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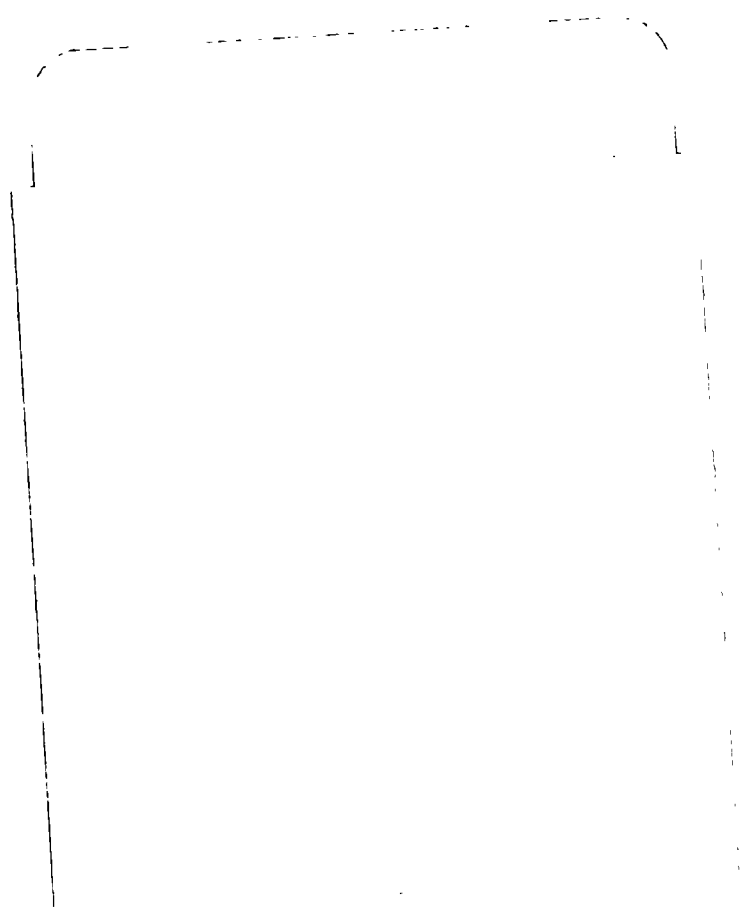
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HASTY REVETMENTS FOR PARKED AIRCRAFT

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DEPARTMENTS OF THE ARMY AND THE AIR FORCE
AUGUST 1975



FIELD MANUAL
No. 5-165
AIR FORCE REGULATION
No. 86-13

DEPARTMENTS OF THE ARMY
AND THE AIR FORCE
WASHINGTON, D.C. 29 August 1975

HASTY REVETMENTS FOR PARKED AIRCRAFT

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*This manual supersedes chapter 16, TM 5-330/AFM 86-3, Vol II, 6 September 1968.



CHAPTER 1

INTRODUCTION

Section I. GENERAL

1-1. Purpose and Scope

This manual provides information to assist in the selection, design, construction, and maintenance of revetments to protect parked aircraft from hostile ground fire and the associated damage effects of exploding fuel and ammunition on or near the aircraft. The contents of this manual are applicable to nonuclear warfare only.

1-2. Changes

Users of this manual are encouraged to submit

comments or recommendations for changes to improve the manual. Comments should be keyed to the specific page, paragraph, and line of the text in which the change is recommended. Reasons should be provided for each comment to insure understanding and proper evaluation. Comments should be prepared using DA Form 2028 (Recommended Changes to Publications and Blank Forms) and forwarded direct to the Commandant, US Army Engineer School, Fort Belvoir, VA 22060.

Section II. AIR FORCE BASE PLANNING AND CONSTRUCTION

1-3. Construction Policy

Current Joint-Service regulations establish policies, responsibilities, and procedures for Army troop construction support to the Air Force. Certain responsibilities of both services are enumerated as follows:

a. Army. The Army will provide troop construction support to the Air Force. This support includes but it is not limited to the following tasks:

(1) Development of engineering design criteria, standard plans, and material to meet standard Air Force requirements.

(2) Reconnaissance, survey, design, construction, or improvement of structures and other facilities.

(3) Rehabilitation and repair of Air Force facilities beyond the immediate emergency recovery capability of the Air Force.

(4) Supply of construction materials and equipment to accomplish the above.

b. Air Force. Headquarters, USAF or the appropriate Air Force command will develop, define, and furnish the Army with aircraft characteristics, layout, and policy guidance. Materials furnished will be in the form of definitive drawings, outline specifications, regulations, organizational tables, manuals, or other appropriate references applicable to construction requirements peculiar to the Air Force.

1-4. Basic Planning Document

AFM 86-3, Planning and Design of Theater of Operations Air Bases, presents information on the planning of Air Force bases in the theater of operations. Basic engineering and logistic data and similar data dealing with a specific phase of air base construction can be found in the manual. This publication may be requisitioned according to the publications supply procedures of the respective services.

Section III. CONSTRUCTION OF AIRFIELD AND HELIPORT PROTECTIVE REVETMENTS

1-5. Airfield and Heliport Construction

It is the responsibility of Army engineers to plan, design within their areas of respon-

sibilities, and construct theater of operations airfields and heliports. To insure that these facilities meet proposed mission requirements,

it is essential that there be close coordination between the responsible engineer officer and all appropriate ground and air commanders (both Army and Air Force). The engineer normally is dependent on the appropriate commanders for information on the types of using aircraft, facility life, geographic boundaries governing site selection, and the time available for construction as dictated by the operational plan. Often the tactical situation will impose limitations on planning, reconnaissance, and site investigation activities, as well as on the actual construction. In some instances, ground reconnaissance and site investigation will be inhibited by presence of the enemy, and maximum use will have to be

made of airphoto interpretation. In such cases, the engineer officer must make every effort to obtain airphoto coverage of the desired area. Normal ground reconnaissance and "on-site" investigations should always be conducted when time and security permit.

1-6. Protective Revetments

The selection of types of revetments to be constructed will be dependent upon the types of aircraft, layout of parking areas, materials available, and the enemy capability to direct fires on parked aircraft. Consideration must also be given to the length of time the facilities will be required.

Section IV. THEATER OF OPERATION CONSTRUCTION CONSIDERATIONS

1-7. Importance of Engineering Study

When requirements for revetments have been determined, it naturally follows that these facilities should be ready for use as early as possible. The need is usually critical, and the accomplishment of a mission often depends on protecting certain airfields. It should be emphasized that, in the effort to obtain such facilities in a minimum of time, *good engineering is the best timesaver*. This statement does not imply that exhaustive field investigations or elaborate plans are necessary; but it does mean that adequate investigation of the site and careful study of the design details are essential for greatest economy in construction time and effort. In the preliminary reconnaissance, it is possible that a few hours spent in soil investigations will provide more effective revetments. The comparison of soil conditions on two possible sites requires extra effort in surveying, but may mean the difference between success or failure. After information on the site is collected and the type of construction is determined, such details as the location of work areas for different equipment, the sequence of operations, the procedure for compaction, and the types and size of revetments must be considered in relation to all possible solutions in order to select the proper one.

1-8. Basic Considerations

The following factors must be considered in all theater of operations revetment design:

a. Economy of Time. Normally, the nearer the airfield or heliport is to the forward area, the more vital the time element becomes. Time is saved by efficient use of manpower, power

equipment, handtools, materials, and other facilities available.

b. Simplicity. Simple designs requiring a minimum of skilled labor and utilizing available materials and supplies should be used.

c. Economy of Materials. Facilities provided by construction projects should be held to a minimum. Materials must be conserved, particularly those shipped from the continental United States (CONUS). Local materials should be used whenever practicable.

d. Location. The location of new construction projects normally is dictated by military necessity. However, existing facilities should be used wherever possible to avoid unnecessary construction.

e. Location. The location of new construction projects normally is dictated by military necessity. However, existing facilities should be used wherever possible to avoid unnecessary construction.

f. Planning and Management. Good planning, careful scheduling, and thorough supervision constitute effective job management. Such management hastens job completion and economizes on time, labor, equipment, and materials. Wherever possible, stage construction should be employed to permit early use of the facility while further construction and improvement continue. The principles of construction management are described in detail in TM 5-333.

g. Terrain. Slopes drainage, vegetation, character of soil, likelihood of floods, and other unusual conditions that may affect construction and layout should be studied.

h. Air Defense Measures and Camouflage. Aerial attack on vital installations must be ex-

pected. The likelihood and effectiveness of such attacks, however, are often minimized by the selection of a site that gives protective concealment, and by the use of antiaircraft weapons and camouflage.

i. *Protection of Existing Facilities.* In all construction, whether in forward or rear areas, care must be taken to prevent destruction of or damage to existing facilities, such as natural drainage channels and culverts. Unnecessary damage to existing facilities, whether above or below the surface, will require repairs and an expenditure of time and manpower far exceeding that required to prevent such damage or destruction.

1-9. Special Considerations

a. *Ballistics.* Tabulated thickness data (table 1-1), which summarize ballistic data in the graphs (app B), and table 1-2 are furnished to show the thickness of protective materials needed to resist penetration by the different types of ammunition listed. Several expedient methods of protection not shown in table 1-1 are discussed in chapter 4 of this manual. The ballistics data and materials are incomplete; however, facilities may be designed to withstand the effects of other ammunition by using chapter 4 as a guide. The manual also covers the design of the recently developed thin-walled revetments and prefabricated moveable revetments. Additional data on roof supports required for protection against indirect fire weapons and bombs can be found in tables 1-3, 1-4, and 1-5.

b. *Revetments.* There are several basic types of protective structures to satisfy various weather, topographical, and military considerations discussed and illustrated, including those that can be constructed with handtools organic to tactical units. However, substantial quantities of earth or other protective materials are needed to achieve minimum protection against all types of ammunition, including small arms.

c. *Ice and Snow Cover.* Minimum thicknesses of snow and ice for protection against small-arms fire are as follows:

New snow, 13 feet.

Tamped snow, 8 to 10 feet.

Frozen snow, 6.5 feet.

Ice, 3.25 feet.

Ice concrete, 1 to 2 feet.

d. *Ice Concrete.* Ice concrete is a dense frozen mixture of sand and water, or sand with gravel and crushed rock and water. At least 10 percent of the mixture should be sand and only enough

water should be added to the mixture to make it slightly liquid. A sheet of the material, 4 inches thick, will freeze solid in 4 to 6 hours at -13°F . In fortification construction it is used for overhead cover, parapets, breastworks, or sandbag filler.

1-10. Terminology

The following terms will be used in the discussion or illustrations contained in this manual.

a. *Optimum Range.* Optimum range is the range at which a particular type of ammunition has the greatest penetrating effect as deter-

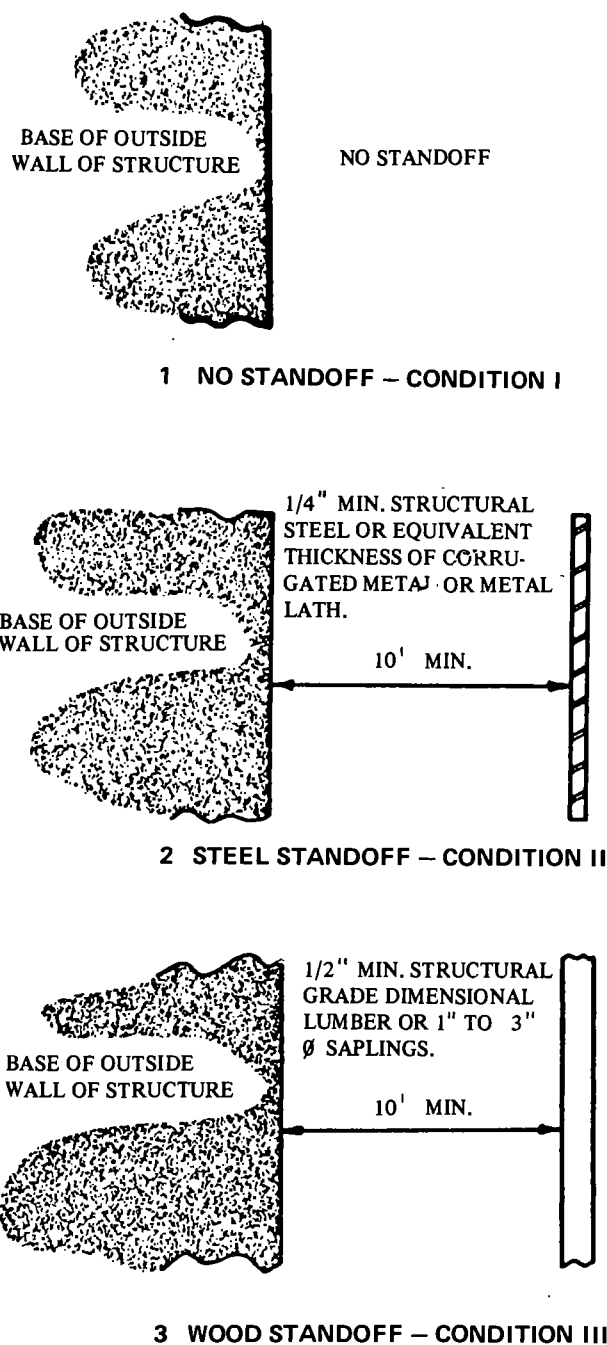


Figure 1-1. Standoff.

Table 1-1. Minimum Thickness of Protective Material Required to Resist Penetration ¹Condition I—No Standoff ²

Material in cm (in)

Types of ammunition	Soil		Sand		Clay		Soil cement bituminous concrete	Concrete	Timber	Aluminum	Steel
	Wet	Dry	Wet	Dry	Wet	Dry					
.30 cal. ball (AP) -----	91 (36)	61 (24)	91 (36)	61 (24)	112 (44)	76 (30)	46 (18)	23 (9)	152 (60)	7 (2.6)	4 (1.3)
.50 cal. ball (AP) -----	137 (54)	91 (36)	114 (45)	76 (30)	203 (80)	137 (54)	46 (18)	23 (9)	305 (120)	11 (4.4)	6 (2.2)
57-mm recoilless rifle ----	46 (18)	30 (12)	46 (18)	30 (12)	91 (36)	61 (24)	51 (20)	25 (10)	51 (20)	23 (9.0)	13 (5.0)
82-mm recoilless rifle ----	102 (40)	69 (27)	104 (41)	69 (27)	203 (80)	137 (54)	107 (42)	56 (22)	122 (48)	53 (21.0)	32 (12.5)
90-mm recoilless rifle ----	152 (60)	102 (40)	160 (63)	107 (42)	305 (120)	203 (80)	168 (66)	84 (33)	193 (76)	81 (32.0)	50 (19.5)
107-mm recoilless rifle ----	183 (72)	122 (48)	178 (70)	122 (48)	355 (144)	244 (96)	213 (84)	107 (42)	224 (88)	102 (40.0)	58 (22.5)
60-mm mortar -----	183 (72)	122 (48)	114 (45)	76 (30)	254 (100)	162 (64)	51 (20)	25 (10)	51 (20)	7 (2.8)	3 (1.0)
81-mm mortar -----	229 (90)	152 (60)	160 (63)	107 (42)	345 (136)	229 (90)	66 (26)	46 (18)	69 (27)	10 (3.7)	4 (1.3)
120-mm mortar -----	262 (103)	178 (70)	178 (70)	122 (48)	457 (180)	305 (120)	81 (32)	41 (16)	91 (36)	12 (4.7)	5 (1.7)

Conditions II and III—.64 cm (¼-in) Steel or 1.27 cm (½-in) Timber Standoff ^{2 3}

.30 cal. ball (AP) -----	46 (18)	30 (12)	46 (18)	30 (12)	56 (22)	38 (15)	23 (9)	15 (6)	76 (30)	4 (1.3)	2 (0.6)
.50 cal. ball (AP) -----	69 (27)	46 (18)	66 (26)	38 (15)	102 (40)	69 (27)	23 (9)	15 (6)	52 (60)	6 (2.2)	3 (1.1)
57-mm recoilless rifle ----	23 (9)	15 (6)	23 (9)	15 (6)	46 (18)	30 (12)	25 (10)	15 (6)	25 (10)	11 (4.5)	6 (2.5)
82-mm recoilless rifle ----	51 (20)	33 (13)	53 (21)	33 (13)	102 (40)	69 (27)	53 (21)	28 (11)	61 (24)	26 (10.5)	16 (6.3)
90-mm recoilless rifle ----	76 (30)	51 (20)	76 (30)	53 (21)	150 (59)	102 (40)	84 (33)	43 (17)	96 (38)	41 (16.0)	25 (9.3)
107-mm recoilless rifle ----	91 (36)	61 (24)	89 (35)	61 (24)	180 (71)	122 (48)	107 (42)	53 (21)	12 (44)	51 (20.0)	28 (11.3)
60-mm mortar -----	91 (36)	61 (24)	56 (22)	38 (15)	127 (50)	81 (32)	25 (10)	13 (5)	25 (10)	4 (1.4)	1.2 (.5)
81-mm mortar -----	114 (45)	76 (30)	79 (31)	53 (21)	168 (66)	114 (45)	33 (13)	18 (7)	36 (14)	5 (1.9)	1.4 (.6)
120-mm mortar -----	132 (52)	89 (35)	89 (35)	61 (24)	229 (90)	152 (60)	41 (16)	20 (8)	46 (18)	6 (2.4)	2 (.8)

¹ Refers to depth a delay fuzed round will penetrate into the various materials. The amount of material required to defeat fragments from the fragmentation ammunition given would be considerably less than shown.

² Conditions I, II, and III are reflected in graphs (fig B-1, B-2, and B-3, respectively.)

³ Timber standoffs are ineffective against .30 and .50 cal. ball (AP) ammo. Therefore, if a timber standoff is used, design the structure as a condition II structure. Then determine if the structure will resist penetration by .30 and .50 cal. ball (AP) ammunition as a condition I structure. If not, increase the thickness of the standoff to the values found in the table for condition I opposite .30 and .50 cal. ball (AP) ammunition.

Table 1-2. Material Thickness Needed for Protection Against Projectiles and Bombs Exploding 15 Meters (50 Ft) Away

High-explosive shells and rockets				General-purpose bombs			
Material	75-mm cm (in)	105-mm cm (in)	155-mm cm (in)	45 kg (100-lb) cm (in)	120 kg (250-lb) cm (in)	225 kg (500-lb) cm (in)	450 kg (1,000-lb)
Solid walls:							
Brick masonry -----	10 (4)	15 (6)	20 (8)	20 (8)	25 (10)	33 (13)	43 (17)
Concrete, plain -----	10 (4)	13 (5)	15 (6)	20 (8)	25 (10)	38 (15)	46 (18)
Concrete, reinforced -----	8 (3)	10 (4)	13 (5)	18 (7)	23 (9)	30 (12)	38 (15)
Timber -----	20 (8)	25 (10)	36 (14)	38 (15)	46 (18)	61 (24)	76 (30)
Walls of loose material between boards:							
Brick rubble -----	23 (9)	25 (10)	30 (12)	46 (18)	61 (24)	71 (28)	76 (30)
Gravel, small stones -----	23 (9)	25 (10)	30 (12)	46 (18)	61 (24)	71 (28)	76 (30)
Earth ¹ -----	38 (15)	46 (18)	61 (24)	61 (24)	76 (30)	-----	-----
Sandbags filled with:							
Brick rubble -----	25 (10)	25 (10)	51 (20)	51 (20)	51 (20)	76 (30)	102 (40)
Gravel, small stones -----	25 (10)	25 (10)	51 (20)	51 (20)	51 (20)	76 (30)	102 (40)
Sand ¹ -----	25 (10)	25 (10)	51 (20)	76 (30)	76 (30)	102 (40)	102 (40)
Earth ¹ -----	51 (20)	51 (20)	76 (30)	76 (30)	102 (40)	102 (40)	127 (50)
Parapets of: ²							
Sand ¹ -----	30 (12)	46 (18)	61 (24)	61 (24)	91 (36)	91 (36)	122 (48)
Earth ¹ -----	61 (24)	91 (36)	122 (48)	91 (36)	122 (48)	152 (60)	-----

¹ Figures based on dry material. If wet material, double figures.

² Figures given to nearest cm (6 in).

Table 1-3. Size of Roof Supports

(1) Timber sizes.

Size of timber (diameter)	Maximum span when used to support 45cm (18 in) of earth
10 cm (4 in)-----	1.2 meters (4 ft)
12.5 cm (5 in)-----	2.0 meters (5 ft)
15 cm (6 in)-----	2.1 meters (7 ft)
17.5 cm (7 in)-----	2.7 meters (9 ft)
20.0 cm (8 in)-----	3.3 meters (11 ft)
22.5 cm (9 in)-----	3.9 meters (13 ft)

(2) Conversion table from timbers to lumber.

Size of rectangular timber	Equal size of round timber
15 x 15 cm (6 x 6 in)	18 cm (7 in)
15 x 20 cm (6 x 8 in)	20 cm (8 in)
20 x 20 cm (8 x 8 in)	25 cm (10 in)
20 x 25 cm (8 x 10 in)	28 cm (11 in)
25 x 25 cm (10 x 10 in)	30 cm (12 in)
25 x 30 cm (10 x 12 in)	33 cm (13 in)
30 x 30 cm (12 x 12 in)	35 cm (14 in)

Table 1-4. Thickness of Laminated Wood Required to Support Earth Cover

Thickness of earth cover in meters (feet)	Span width in meters (ft)					
	.76 (2½)	.91 (3)	1.06 (3½)	1.22 (4)	1.52 (5)	1.83 (6)
	Thickness of laminated wood in cm (in.)					
.46 (1½)	2.5 (1)	2.5 (1)	5 (2)	5 (2)	5 (2)	7.6 (3)
.61 (2)	2.5 (1)	5 (2)	5 (2)	5 (2)	5 (2)	7.6 (3)
.76 (2½)	2.5 (1)	5 (2)	5 (2)	5 (2)	5 (2)	7.6 (3)
.91 (3)	5 (2)	5 (2)	5 (2)	5 (2)	7.6 (3)	7.6 (3)
1.06 (3½)	5 (2)	5 (2)	5 (2)	5 (2)	7.6 (3)	7.6 (3)
1.22 (4)	5 (2)	5 (2)	5 (2)	5 (2)	7.6 (3)	10 (4)

Table 1-5. Center to Center Spacing of Wooden Stringers Required to Support 2.54 cm (1-in) Thick Wood Roof With Earth Cover

Thickness of earth cover in meters (feet)	Span width in meters (feet)					
	.76 (2½)	.91 (3)	1.06 (3½)	1.22 (4)	1.52 (5)	1.83 (6)
	Center to center spacing of stringers in cm (in.)					
.45 (1½)	12.19 (40)	9.14 (30)	6.71 (22)	4.88 (16)	3.05 (10)	5.18 (18)*
.61 (2)	10.05 (33)	6.71 (22)	4.88 (16)	3.66 (12)	2.44/6.1 (8/20)*	4.27 (14)*
.76 (2½)	8.23 (27)	5.18 (18)	3.66 (12)	3.05 (10)	4.88 (16)*	3.05 (10)*
.91 (3)	6.71 (22)	4.27 (14)	3.05 (10)	2.44/6.1 (8/20)*	4.27 (14)*	2.44 (8)*
1.06 (3½)	5.18 (18)	3.66 (12)	2.44/7.32 (8/24)*	5.18 (18)*	3.66 (12)*	2.44 (8)*
1.22 (4)	4.88 (16)	3.05 (10)	2.44/6.1 (8/20)*	4.88 (16)*	3.05 (10)*	2.13 (7)*

Stringers are 5 x 10cm (2 in x 4 in) except those marked by an asterisk () which are 5 cm x 15cm (2 in x 6 in).

mined by ballistic tests on which the data in table 1-1 and appendix B are based.

b. Standoff. A standoff (fig 1-1) is a steel or wood curtain erected approximately 10 feet in front of a protective structure to detonate shells and thereby reduce the penetrating effect.

c. Angle of Repose. The angle of repose is the steepest slope at which a material, such as earth, will stand without sliding.

d. Penetration Resistance Factor (PRF). The PRF is the ratio of the actual thickness of the material which may be used to the thickness of that material which is given in table 1-1 as adequate to resist penetration by a particular type of ammunition. When a structure is constructed of a single material, the PRF MUST

BE EQUAL TO OR GREATER THAN 1.00 to safely resist penetration. If a structure is constructed of several thicknesses of different materials, the sum of the PRFs of the individual thicknesses must equal 1.00 to safely resist penetration.

e. Condition. A construction "condition" as used herein refers to a protective structure with a standoff (conditions II and III) or without a standoff (condition I) (b above) (fig 1-1).

f. Gravity Revetment. A gravity revetment is a type of earth embankment in which earth is piled against a retaining wall at its angle of repose (c above).

g. Earth Revetment. An earth revetment is a type of earth embankment in which interior and

exterior slopes are placed at an angle no greater than the angle of repose.

h. Bulkhead. A bulkhead type of protective structure consists of two retaining walls with earth between the walls.

i. Free Standing Wall. A free standing wall is a wall requiring no external braces or guying devices.

1-11. Graphs

a. Condition I. The graphs represented in ① through ⑪, figure B-1, provide detailed ballistic data for different types of ammunition under condition I when no standoff is used. Each graph refers to one of the 11 types of protective material discussed.

b. Condition II. ① through ⑪, figure B-2, provides penetration data under condition II when a steel standoff is used.

c. Condition III. ① through ⑪, figure B-3, provides penetration data under condition III when a wood standoff is used.

1-12. Concepts of Aircraft Protection

Revetments generally will shield the lower parts of the aircraft and provide limited protection to the upper parts. It is normally not planned to build overhead protection or structure high enough to shield the upper portions of large cargo-type helicopters. However, the revetment plans included herein are flexible so they can be adapted to varied situations pro-

vided there is enough material to construct larger protective structures.

a. The size and shape are very important considerations in determining the overall effectiveness of any revetment system. They are usually dictated by command or operational restrictions imposed on equipment and may be difficult to control. For maximum effectiveness, however, a revetment should be as close to and as near the height of the equipment it is protecting as is practical.

b. It does not appear practical to construct revetments high enough to protect all of the critical areas of large cargo-type helicopters. Tests have shown that blast effects from mortar and rocket shells detonating nearby would require sound structural support systems to prevent blowover. As the height of a revetment increases, the difficulty of supporting it also increases.

c. If manpower, equipment, and material resources are committed to provide protection, every field commander will want definite results for the effort expended. The smaller utility or attack helicopters can be adequately protected by inclosing them with high-walled revetments. Perhaps the protection of some combat-ready aircraft, of operational necessity, must be minimal, but nonalert aircraft or aircraft in maintenance or storage areas can be provided adequate fragmentation protection by properly positioned high-walled revetments.



CHAPTER 2

WEATHER AND TOPOGRAPHICAL CONSIDERATIONS

2-1. Weather Conditions

A factor in the construction of earth revetments is the effect of heavy rains or other extreme weather conditions. Erosion over an extended period will reduce the resistance to penetration. Periods of wet weather produce soil moistures that generally are high and cause changes in the strength of materials. Soils with a high moisture content have very little strength or resistance to penetration. Dampness has an adverse effect on most protective materials, including wood and steel, requiring treatment or protection against deterioration for prolonged use.

2-2. Topography

The topography of the area near an airfield should be considered in determining the protective requirements for parked aircraft. High ground within a range of 3,500 meters that offers good observation for effective mortar or direct fire may destroy the effectiveness of revetments unless preparations are made for an active perimeter defense including effective counterfire. Similarly, wooded areas, villages, or other sites permitting concealment close to parked aircraft give opportunities for guerrillas and saboteurs to assemble. These factors indicate a need for active defense measures in addition to passive fortification measures.



CHAPTER 3 MILITARY CONSIDERATIONS

3-1. Local Environmental Considerations

a. Active Measures. An active perimeter defense against infiltration, sabotage, or similar tactics substantially increases the effectiveness of revetments and other passive defense measures. For this reason, confining protective construction to an area that can be adequately defended is desirable. If dispersal of aircraft is possible and consistent with active defense measures, varied parking patterns provide less profitable targets for indirect fire weapons.

(1) Studies of the vulnerability of aircraft to most indirect fire weapons have shown that parking aircraft along an area of extreme elongation, such as parallel to a runway, will provide the lowest overall aircraft vulnerability. Parking on an unused runway or other elongated area parallel to the main runway may be successfully used if the parking area is sufficiently separated from the main runway to preclude significant damage to both runway and parked aircraft by fire directed at a single aiming point. For most Army airfields, which are relatively small and unimproved, compact parking areas (e.g., square or round) are best. The size of the parking area should be sufficient to allow enough dispersion so that chances of damaging two aircraft with a single round are minimized.

(2) Hardened parking surfaces, common to the larger airfields in the form of landing mat, increase lethal areas of bursting mortar rounds. They probably have the same effect on other ammunition. Effects of other hardened surfaces, such as bituminous materials and concrete, are not known but it is likely that these also increase fragment effectiveness. Where parking areas can be adequately maintained on sod or on some surface which does not cause fragment ricochet, a reduction in damage from indirect-fire attacks should result.

(3) Figures 3-1 through 3-3 show some conceptual layouts of airfields providing random dispersal of parking areas, for theaters of operations when the enemy has the capability to gain air superiority for limited periods of time. For those theaters of operation when enemy aircraft either do not exist or do not have the capability

to gain air superiority, figures 3-4 and 3-5 would apply.

(4) Lateral clearance for rear area operations should be 150 meters (500 ft) from the centerline of the runway to:

- (a) Near edge of taxiway.
- (b) Near edge of parking apron.
- (c) Fixed or movable objects.

For support area operations decrease the above clearance to 90 meters (300 ft).

b. Passive Measures. Revetments should be tied in with and strengthen other forms of protection including dispersion, camouflage, and active defense measures. The use of protective structures for parked aircraft should increase the combat effectiveness of the unit. As in the case of fortifications constructed to protect personnel and weapons, the decision as to the type will be determined by the tactical situation including enemy capabilities; the availability of materials, construction equipment, and personnel to perform the required work; and an available area for construction.

3-2. Weapons Capabilities

a. Analysis. The information listed in table 1-1 and plotted in the ballistics data graphs (app B) provides the basis for planning revetments. The tabulated data and graphs show the penetration capabilities of the different types of ammunition at optimum range against wet and dry soils, soil cement, concrete, timber, aluminum, and steel. Ammunition types for which PRFs have been developed are those commonly employed. These same ammunition types were used to evaluate the expedient fortifications.

b. Effectiveness. Revetments should resist penetration by the most effective type of ammunition to which the structure is likely to be exposed. Table 1-1 shows that 120mm mortar and 107mm rifle ammunition generally are the most effective against the materials considered. A standoff (fig 1-1) will reduce the effectiveness of most ammunition by detonating it before it strikes the revetment. Consequently, a lesser thickness of protective material can be used with a standoff than without one. The data in table 1-1 are based on a PRF of 1.00 for com-

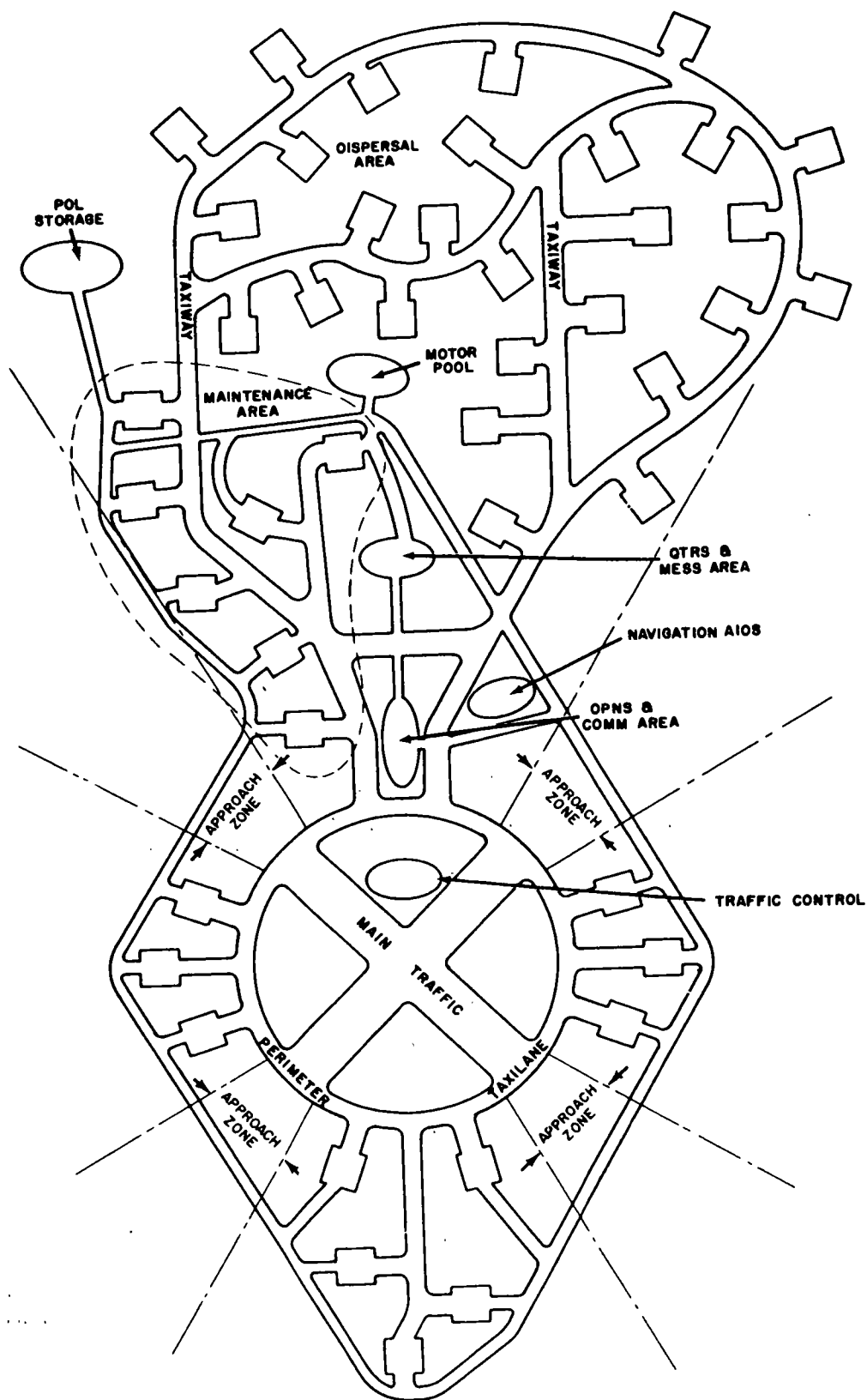


Figure 3-1. Heliport layout.

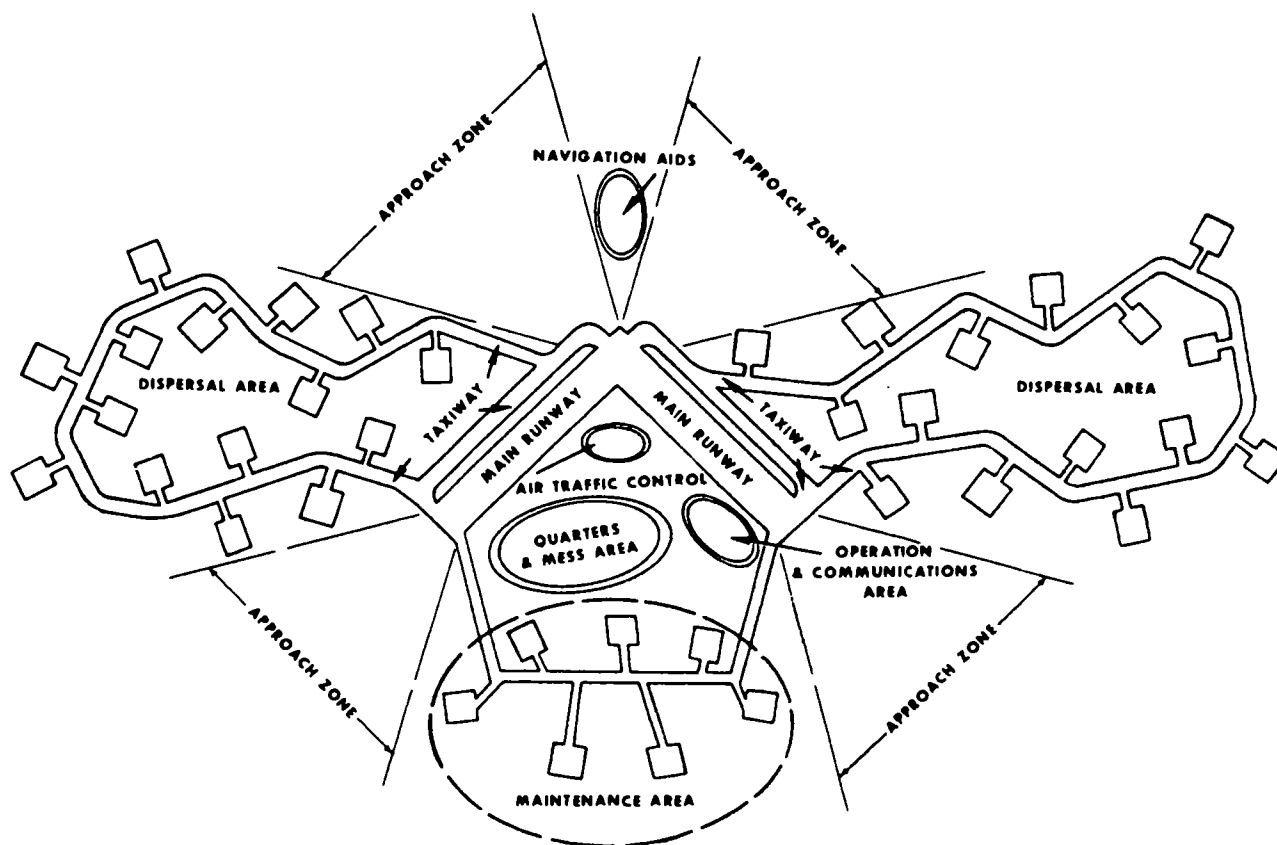


Figure 3-2. Layout, all types of aircraft.

parative purposes since this factor provides the minimum thickness of material required to resist penetration by a given type of ammunition at optimum range. The graphs (app B) show the thickness of material required for PRFs which are smaller or larger than 1.00. An estimate can be made of the amount of protection provided by

various thickness of material. For field expedient methods the percent effectiveness is the approximate amount of shrapnel which will be stopped by the revetment.

Note. PRFs of 1.00 or greater are effective. PRFs less than 1.00 are less effective. Emphasis should be placed on designing structures with a PRF equal to or greater than 1.00.

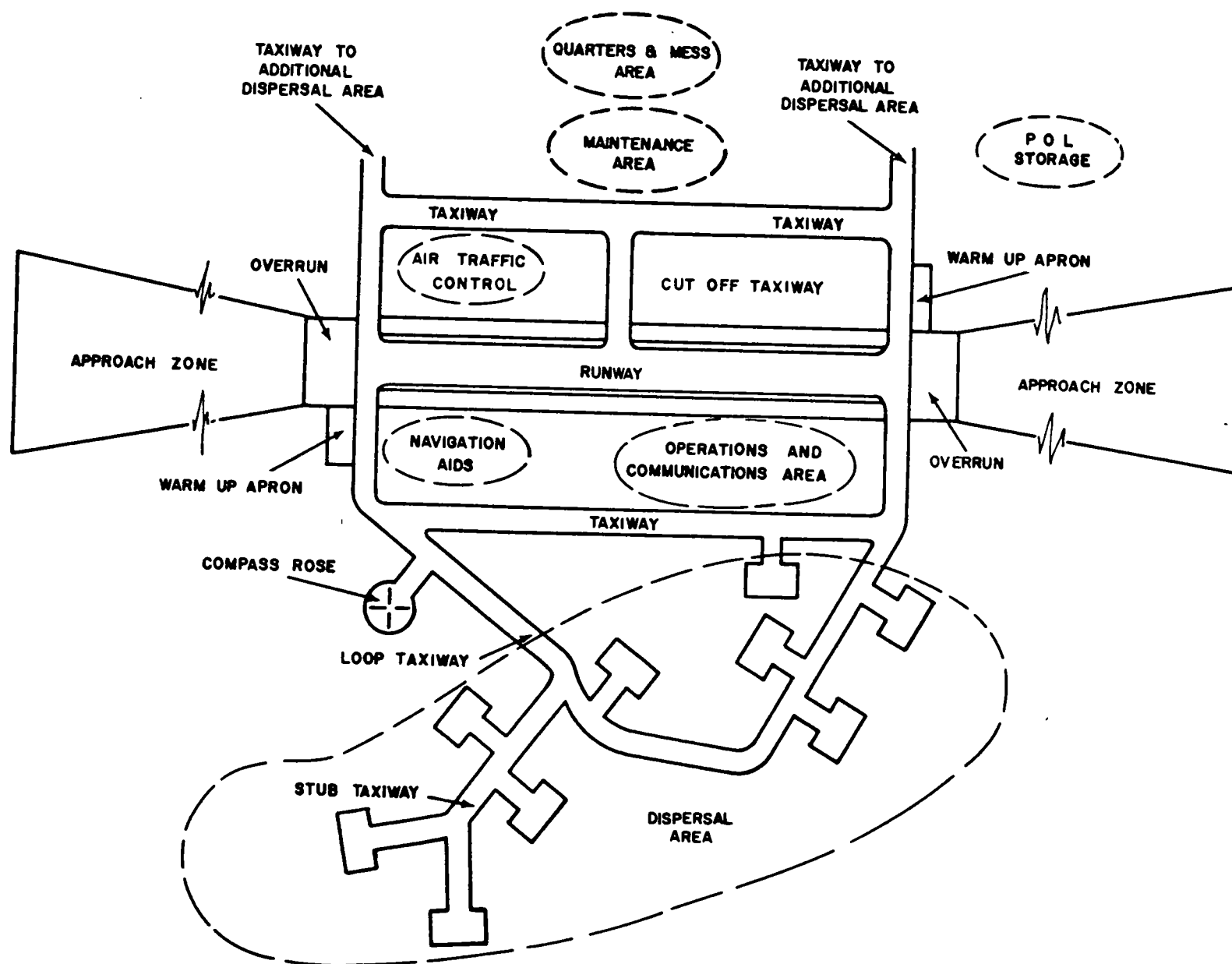


Figure 3-3. Fixed wing aircraft layout.

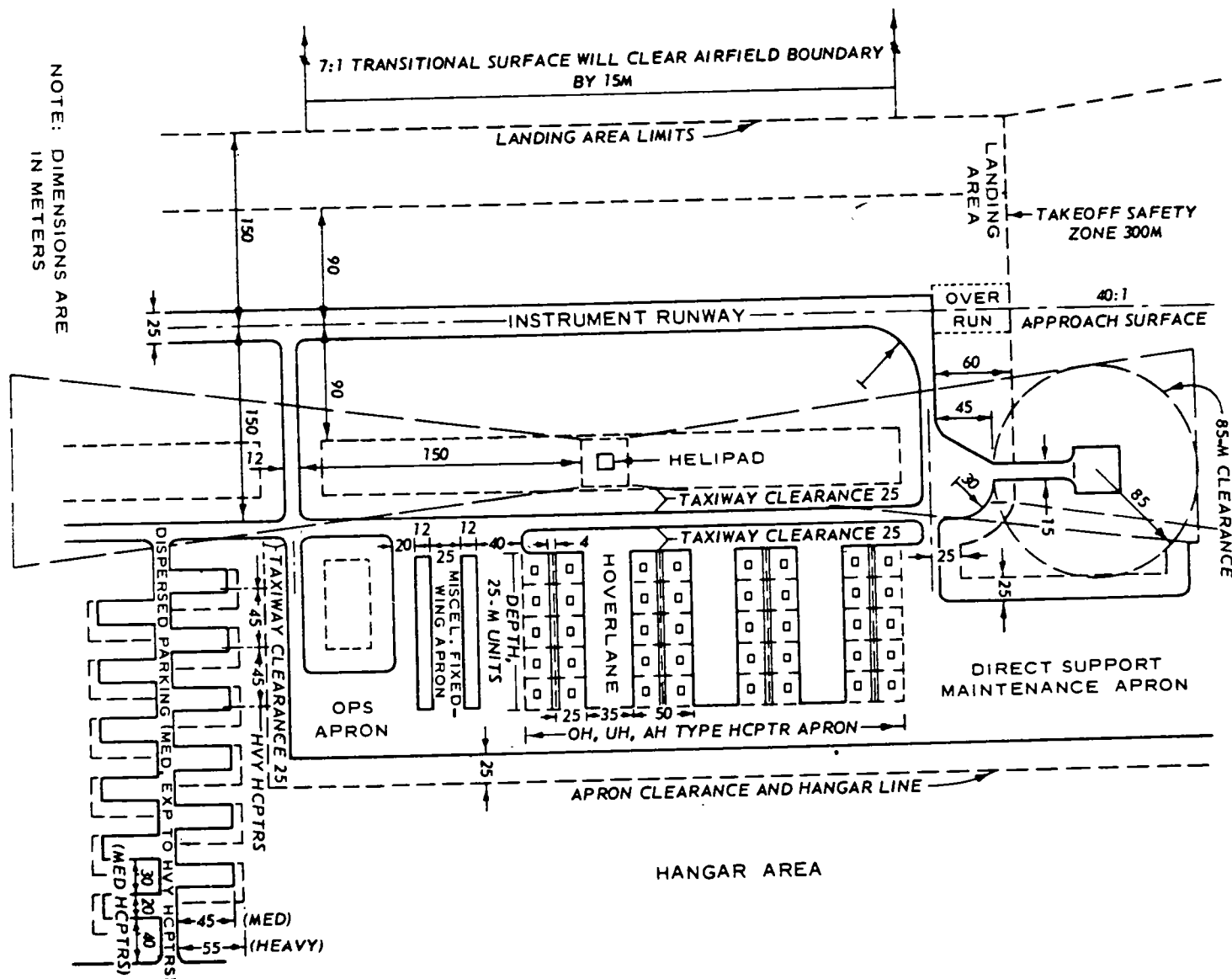
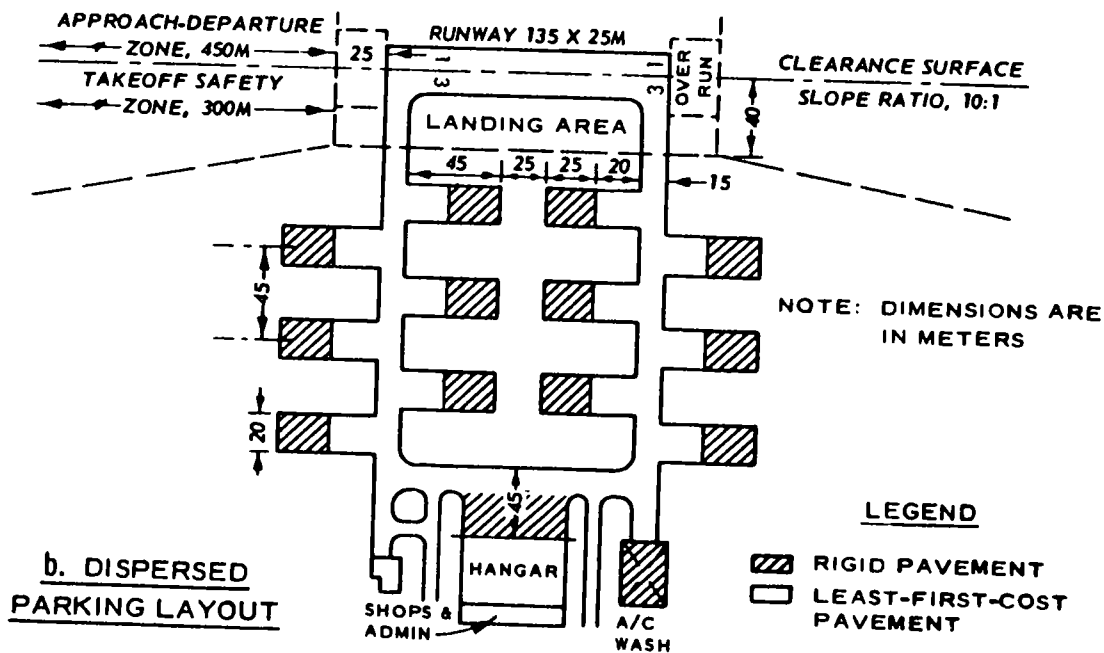
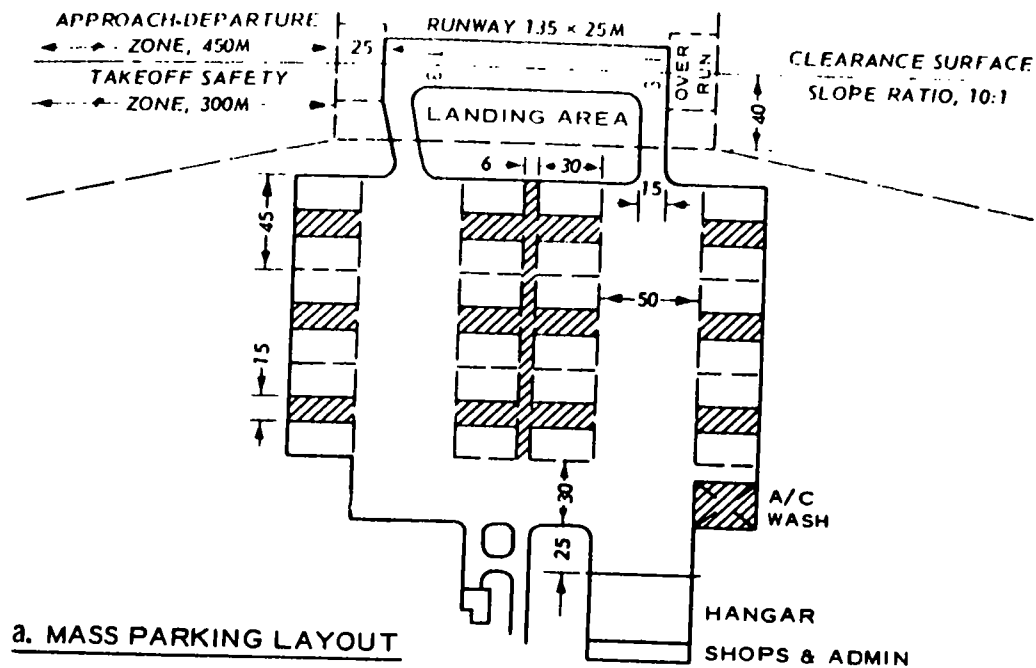


Figure 3-4. Heliport layout—friendly air superiority.



NOTE: DIMENSIONS ARE IN METERS

Figure 3-5. Layout, all types of aircraft—friendly air superiority.

CHAPTER 4 PROTECTIVE MATERIALS

4-1. Primary Revetment Materials

a. Basic Considerations. The selection of materials for field construction, particularly for revetments, depends on their availability. A discussion of the characteristics of different materials available for revetments must include their resistance to penetration as shown in the graphs in appendix B. This chapter discusses the relative protective qualities of primary and expedient protective materials. The techniques of construction, preservation, and repair or rehabilitation will be discussed later in this manual.

b. Effects of Moisture. Wet soil may be used for revetments if dry material cannot be obtained, but it is uneconomical since larger quantities are required to resist penetration. Table 1-1 shows that wet soil must be about one half again as thick as dry soil to resist penetration by a given type of ammunition. Thus selecting dry soil for earth revetments and providing a waterproof cover for them conserve manpower and materials. An expedient test that can be used in determining moisture content in soils, for fortification purposes, is to observe the reaction of a handful of soil when squeezed into a ball. If it keeps the shape of a ball, it is regarded as a wet soil. Conversely, if it fails to stick together, it is considered a dry soil. Of the various soils, wet clay can be penetrated most easily and is the least effective revetment material. Dry sand has the most resistance to penetration and therefore is the most desirable soil for revetment purposes.

c. Soil Cement. This material is obtained by mixing 1 part by weight of portland cement with 10 parts by weight of dry earth or 6 parts by weight of sand-gravel. The mixture is placed in sandbags and the cement sets as the bags take on moisture. This procedure extends the useful life of sandbags which normally deteriorate quite rapidly, particularly in damp climates. Filled sandbags may also be dipped in a thin mixture of cement and water. Soil cement can be produced in large quantities by following the procedures described in TM 5-330. Soil cement is highly resistant to mortar and ball ammunition

but has much less resistance to recoilless rifle ammunition.

d. Concrete. The characteristics, mixture, placement, reinforcement, and curing of concrete and the construction of forms are explained in TM 5-742. Concrete construction should not be undertaken except under qualified supervision to avoid uneconomical use of critical materials.

e. Timber. Timber is useful as a retaining wall for earth revetments. In addition to support, it increases the effective resistance of the revetment. Timber used for this purpose may be either hard or soft but should be free of knots and other imperfections that would affect its rigidity or resistance to penetration. When used against earth, timber should be treated with a preservative such as tar or creosote to prolong its usefulness.

f. Steel. Steel for use in erecting soil-filled revetments may be available in several forms such as corrugated metal, sheet piling, metal landing mat, and others. The thickness of these materials should be considered in determining the resistance to penetration. If the material has holes larger than 1.27cm ($\frac{1}{2}$ in), it will not properly confine the soil fill material.

Note. All types of soil-filled revetments .3m (12 in) thick are 100 percent effective at defeating mortar and rocket shell fragments at a 1.5m (5 ft) detonation-to-structure range providing they are structurally adequate to withstand blast effects.

g. Plastic Armor. Plastic armor is an asphalt mix made into sheets or plates by pouring it into forms. A 5cm (2 in) thickness of asphalt mix gives considerable protection from both small arms and conventional weapons fire. Field expedient asphalt mixes can be used but will not be as effective as hot plant mixes. The fragment defeating capability is directly related to the aggregate size used in the asphalt mix. The most effective size has been found to be coarse aggregate .64cm ($\frac{1}{4}$ in) or larger. To increase the penetration resistance factor, layers of plastic armor should be used rather than a greater thickness of asphalt. Several form types are shown in figures 4-1 through 4-4. The asphalt can be left in these forms and installed as protection if the asphalt itself is not sufficient.

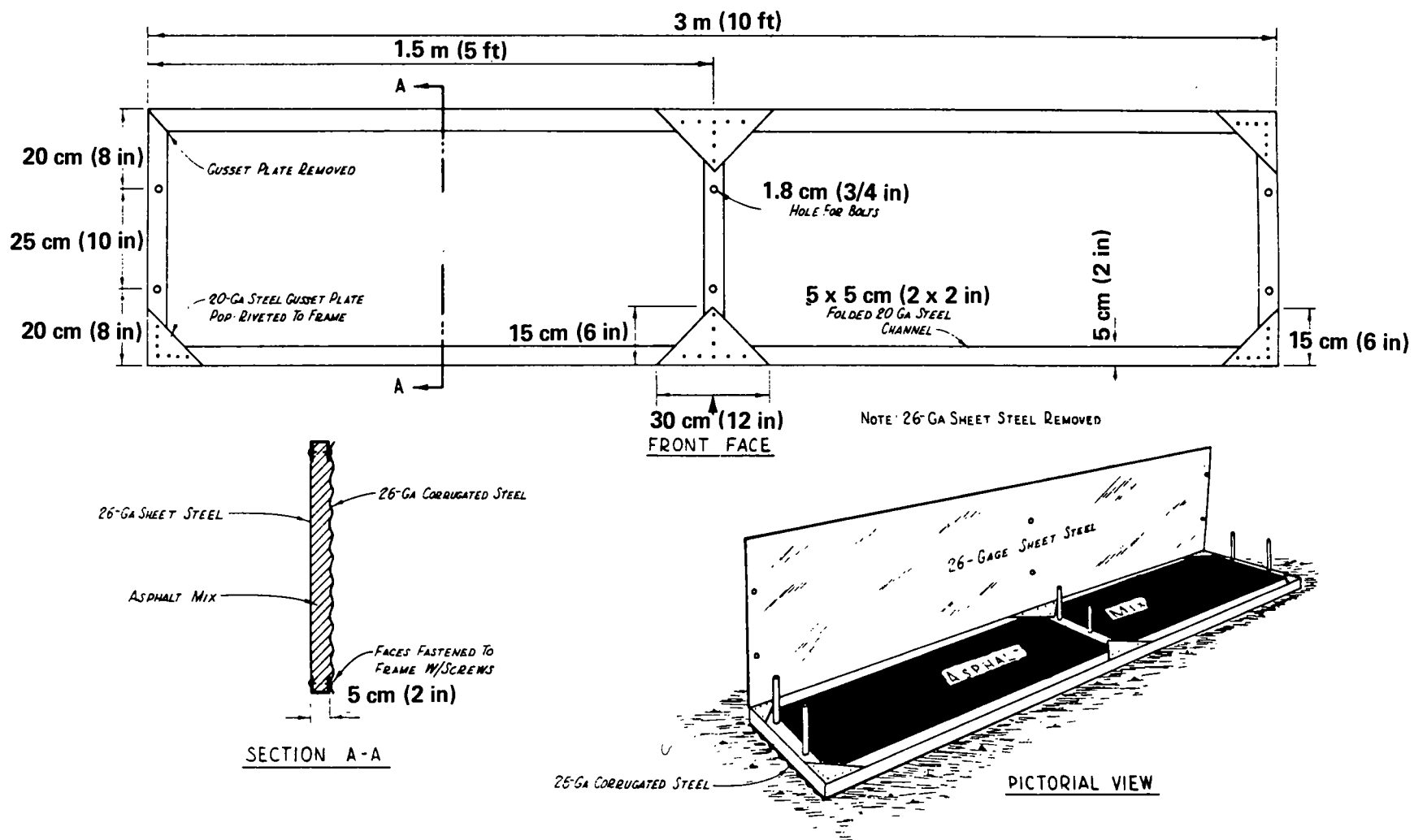


Figure 4-1. Details of plastic armor plate panel 1 (sheet steel with metal frame).

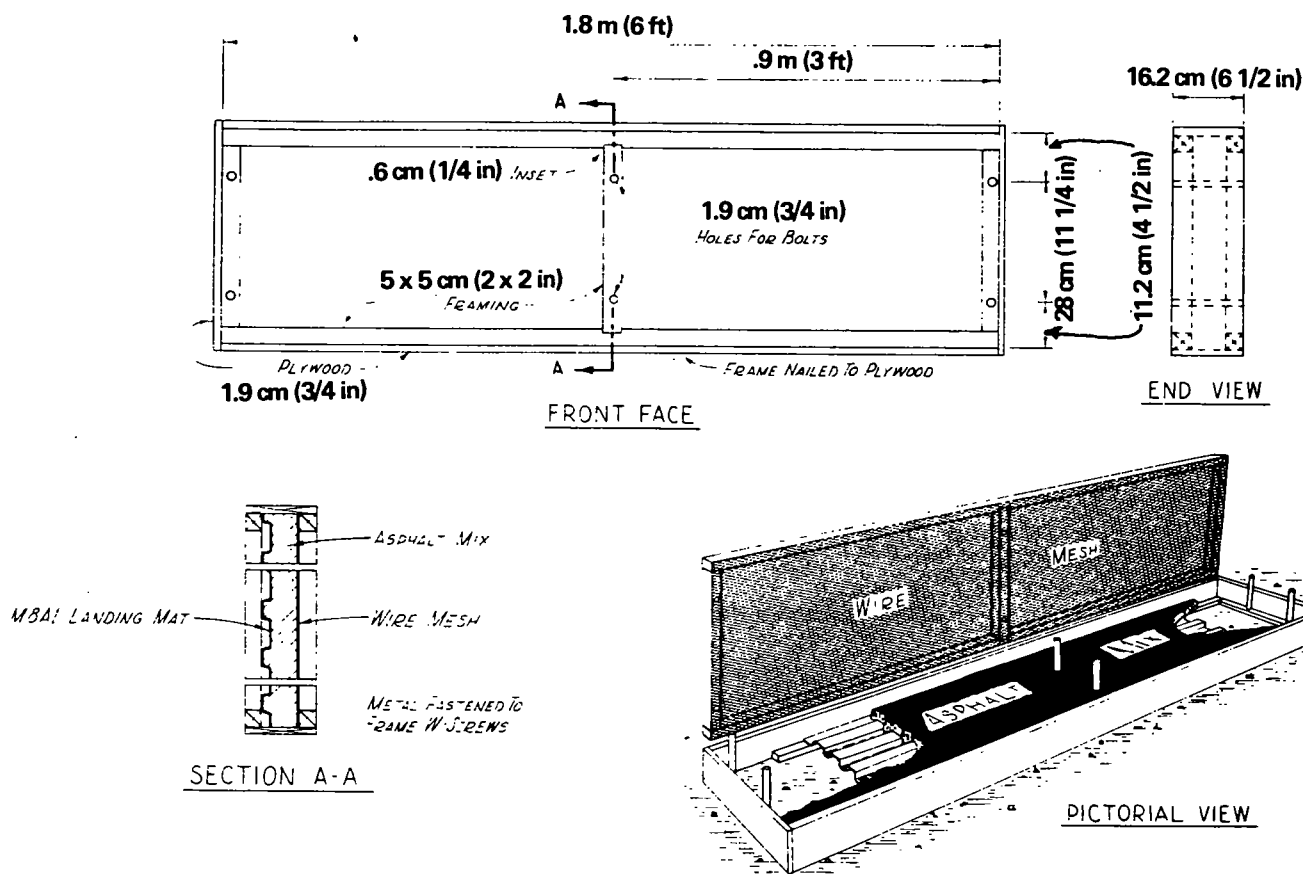


Figure 4-3. Plastic armor plate panel 4 (M8A1 landing mat with wire mesh).

When using plastic armor, it is most effective with at least one plate left attached to it and this should be on the friendly side. If small arms fire is a threat, the M8A1 landing mat is the most effective plate to use. Two-inch plastic armor of 60 percent coarse aggregate, 30 percent mineral filler, and 10 percent asphalt binder (by weight) with attached 26-gage steel sheets, is 100 percent effective at 9 meters (30 ft) from detonating point to wall. These protective walls must be braced and anchored to prevent blast effects from knocking them down.

4-2. Expedient Revetment Materials

a. Landing Mat. A suitable wall effective against fragments can be constructed with landing mat which is no longer suitable for runways. Two thicknesses of M8A1 will give good fragment protection even without being filled with soil. The A-shaped revetment (fig 4-5) will stop most fragments from the 81mm, 82mm, 120mm, and 4.2-inch mortars and 107mm rockets, and approximately 75 percent of the 122mm rocket fragments at a round-to-structure distance of 9 meters (30 ft) (table 4-1). The percent effectiveness is the number of fragments completely stopped by the material and is expressed as:

$$\% \text{ effectiveness} = 1 - \frac{\text{number of penetrating fragments}}{\text{total number of impacting fragments}} \times 100$$

To construct this revetment a 3.7 meter (12 ft) length of mat is cut and folded as shown in figure 4-5. Folded sections are placed end to end to form a wall. A steel angle or pipe is run the length of the wall and welded to each section to hold the wall in place. Finally, the landing mat wall is anchored to the ground so it cannot be blown over by aircraft movement or blast effects. Two pieces of M8A1 mat set to form parallel, vertical walls, separated by a distance of .3 meter (1 ft) and properly supported, will also function as good fragment protection. As with the A-shaped revetment, a pipe or steel angle should be run along the length of the wall and welded to each section to hold them in position. It must also be anchored to the ground against wind and blast effects. When the parallel wall M8A1 revetment is filled with soil, it will stop all fragments from 81mm, 82mm, and 120mm and 4.2-inch mortars and 107mm and 122mm rockets detonating as close as 1.5 m (5 ft). The use of 10x30cm (4-in x 12-in) timbers spaced at 1.8 m (6

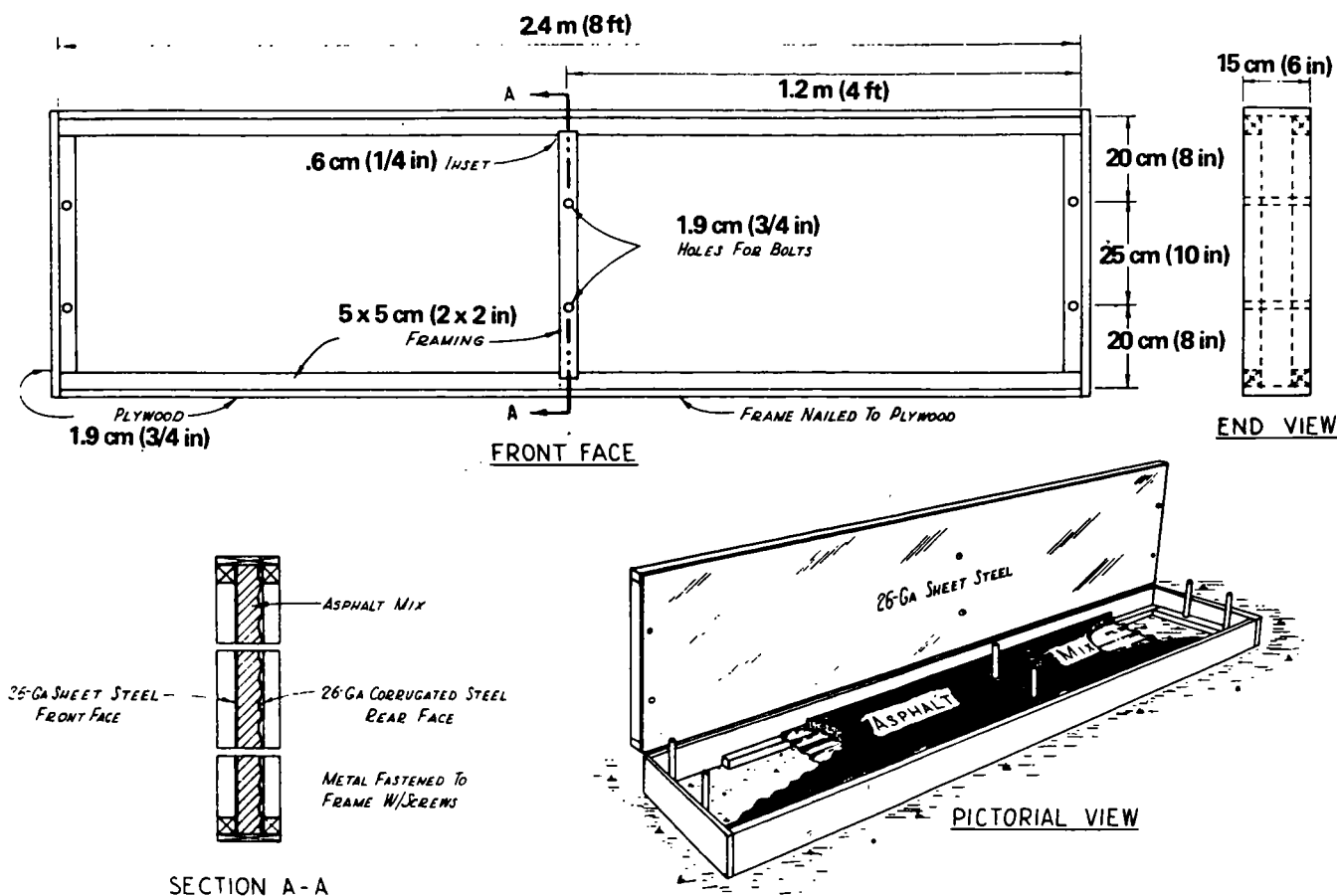
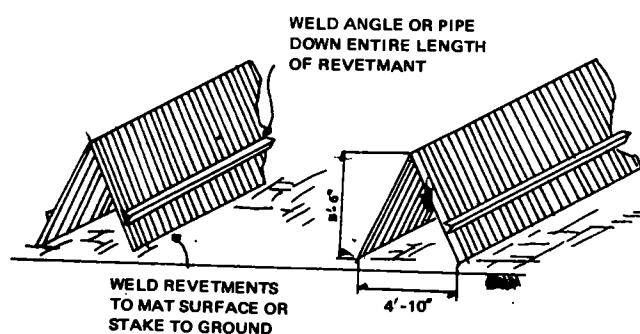
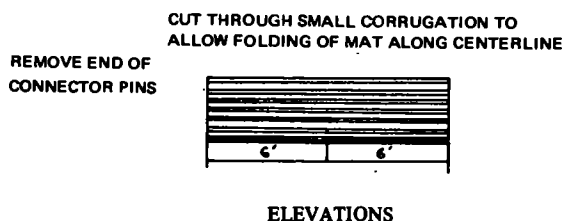


Figure 4-4. Plastic armor plate panel 6 (corrugated and sheet steel with plywood).



PICTORIAL VIEW



ELEVATIONS

Figure 4-5. A-shaped M8A1 landing mat revetment.

ft) center-to-center (or at every mat joint) is recommended to provide stability and maintain the mat spacing. A bolt is inserted through the mat on each side of the post to hold it in position. Some type of bearing plate is used to reinforce the connection along the bolt line. If practical, the end locking pins are engaged on the revetment to make a rigid connection at the end joints.

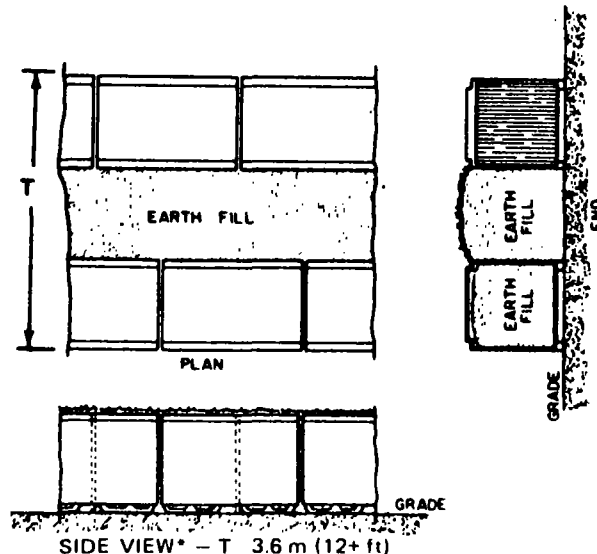
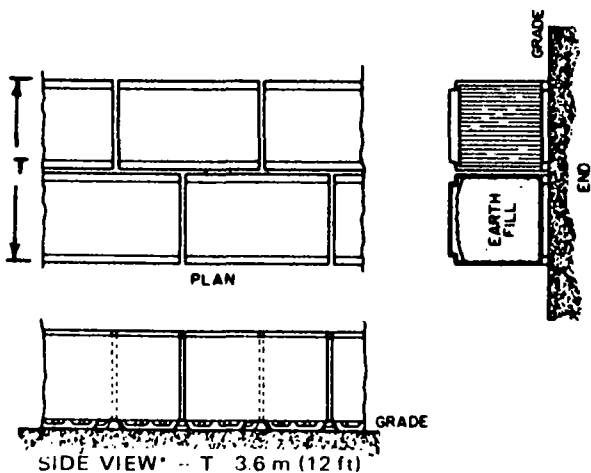
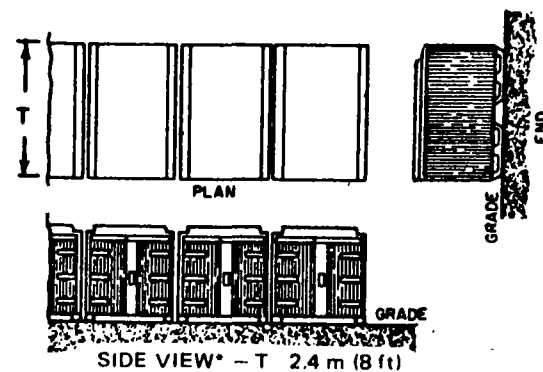
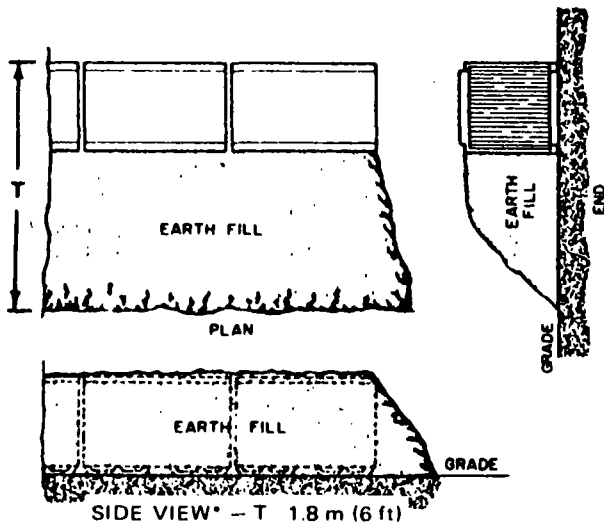
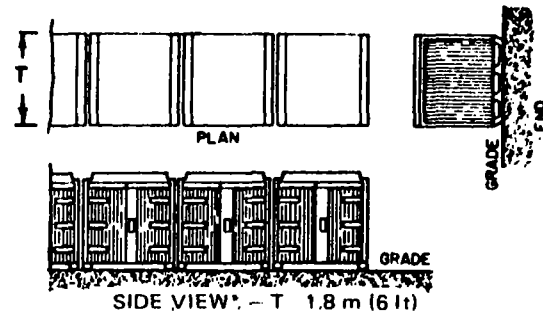
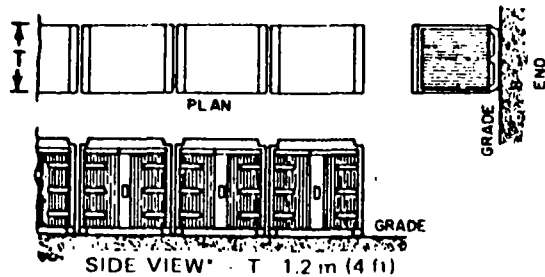
b. Corrugated Metal. If available in sufficient quantity, this material is a satisfactory substitute for revetment retaining walls and bulkheads, although its lack of rigidity will require additional quantities of wales and vertical supports to withstand the pressure of the earth fill.

c. Plywood. One or more layers of plywood will serve as an effective field expedient protective wall. As more layers of plywood are added, the amount of protection increases accordingly. Table 4-2 shows the effectiveness of up to three layers of 1.91cm (3/4-in) fir plywood. The percent effectiveness is defined as in *a* above. The plywood must be braced and anchored to provide stability against blast and aircraft move-

ment. If time allows, the plywood could be formed into box-type structure and filled with soil. This will increase protection considerably above that furnished by the layers of plywood.

d. Boxes.

(1) Ammunition boxes filled with earth provide limited protection and can be used as a retaining wall or bulkhead if they are adequately supported with wales and vertical supports.



* THICKNESS

(2) A substantial bulkhead revetment can be provided using salvage containers (Conex type or similar) filled with moderately dry sand or soil (fig 4-6). These salvaged containers will normally require patching and sealing of holes to prevent moisture accumulation, and to prevent loss of sand or soil.

e. Fifty-Five-Gallon (200 Liter) Drums. Unserviceable 200 liter (55-gal) drums can be

Figure 4-6. Bulkhead revetment using containers.

Table 4-1. Summary of M8A1 Landing Mat Effectiveness (A-Shaped or Square Configuration)

Range	1.5 m (5 ft)	3 m (10 ft)	6 m (20 ft)	9 m (30 ft)
Threat	% Effective			
81mm	95	98	98-100	98-100
82mm	98	98-100	98-100	98-100
4.2 in	76	82	91	98
107mm	70	79	89	96
120mm	98	98-100	98-100	98-100
122mm			70	78

Table 4-2. Plywood Effectiveness at 9 Meters (30 Ft) Round-to-Wall Distance

	1.91 cm (¾ in) Thick	3.8 cm (1½ in) Thick	5.72 cm (2¼ in) Thick
Threat	% Effective		
81mm	60	82	91
82mm	64	86	97
4.2 inch	24	55	71
107mm	47	71	86
120mm	60	84	91

stacked in varied patterns and then filled with sand to provide limited protection. Drums can be stacked for extra height but must be welded. A steel angle or pipe should run the length of the wall and be welded to each drum for added stability. Each level must be welded to the level below.

f. Combining Materials. If they are available and construction skills permit, the combined use of two or more materials usually results in a more effective revetment. For example, the use of timber and soil (dry soil) without standoff may be considered by referring to table 1-1 or the graphs ② and ③, fig B-1 for the different materials shown. Twenty cm (8 in) timbers will

provide a PRF of 0.3 (20cm (8 in)) actual thickness divided by the 68cm (27 in) of timber given in table 1-1 and appendix B as adequate to resist penetration against 81mm mortar ammunition. The total PRF must equal 1.00, so a sufficient thickness of dry soil must be added for an additional PRF of 0.7 ($1.0 - 0.3 = 0.7$). Since a single thickness of 152cm (60 in) of dry soil will resist penetration by 81mm mortar ammunition, 106cm (42 in) ($0.7 \times 152 = 106\text{cm}$) ($0.7 \times 60 = 42\text{ in}$) of dry soil must be combined with 20cm (8 in) timbers for a PRF of 1.00. This design, featuring a combination of materials, represents a savings in materials and manpower and reduces the area required for the structure.



CHAPTER 5 REVETMENT DESIGNS

Section I. BASIC DESIGN FACTORS

5-1. Preliminary Considerations

Since space limitations affect airfield size, as well as the type, pattern, and layout of revetments, an investigation should be made to determine the airfield area, anticipated aircraft population, duration of occupancy, and area next to the airfield available for dispersal of aircraft. Each airfield will present problems in one or more of the above areas to which general guidelines apply. If lack of available space prevents the dispersal of aircraft, this fact may influence the type of revetment in one part of the field and minimum limited protection in another area. Topography of the area, including the presence of barriers such as a deep stream next to the field, may minimize the protection required. Maximum aircraft protection consistent with requirements and available resources, should be the guiding consideration for all revetment construction.

5-2. Size and Shape of Revetments

a. The size and shape of a revetment are important in determining the total effectiveness of a revetment system (para 1-12). The height of a revetment system can be critical. With regard to utility helicopter revetments, if a "fly in/fly out" capability is necessary, this limits the height and therefore the effectiveness of the revetment system.

b. Figure 5-1 illustrates effectiveness of revetment configurations for the utility helicopter against an 81mm mortar. A round landing within the shaded area is likely to cause some damage to the helicopter.

(1) As shown in *a*, figure 5-1, there is a 100 percent probability that 81mm mortar fragments detonated within a 40-meter (130-ft) radius from an unprotected helicopter will cause some damage to the helicopter.

(2) A 1.7-meter (5.5 ft) high parallel wall shown in *b*, figure 5-1, will reduce the damage area by approximately 5 percent. There is a 95 percent probability that the helicopter's transmission and turbine will receive some damage from 81mm mortar fragments.

(3) With *c*, figure 5-1, the height of the parallel walls is 3.6 meters (12 ft). This revetment does protect the critical components of the helicopter from a near-miss detonation of the 81mm mortar occurring along the outside of the revetment walls.

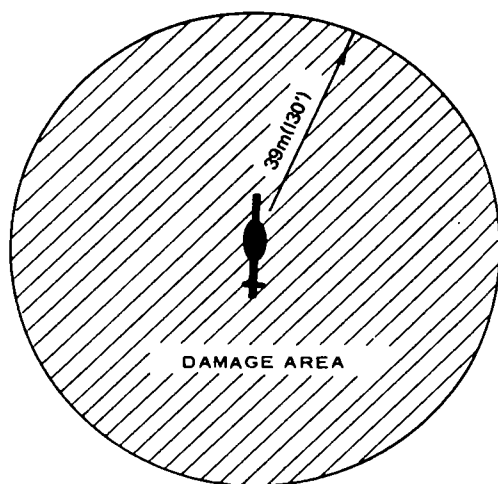
(4) Figure 5-1*d* shows the addition of a rear wall to the revetment. The damage area from the 81mm mortar will be reduced by 65 percent. The probability of damage is lessened to 35 percent. If a fixed or portable door is provided for the extended height (36 meters (12 feet)) of the U-shaped revetment, a 5 percent probable damage area will result. In this last case the 81mm mortar shell would have to explode within the revetment walls to cause damage.

c. The fragment pattern of an 81mm mortar has a varying effectiveness depending upon the height of the revetment. Figure 5-2 shows a helicopter superimposed over a typical fragment pattern from a vertically oriented 81mm mortar shell. The mortar shell was detonated at 9 meters (30 ft) and 15 meters (50 ft) distance from the centerline of the helicopter. Figure 5-2 also shows projected protection limits provided by revetments 1.7 meters (5.5 ft), 2.7 meters (9 ft), and 3.6 meters (12 ft) high. The most important point to remember is that as the round hits farther away from the aircraft, the effective heights of the protection provided by the revetment become less and less up to the effective range of the mortar fragments.

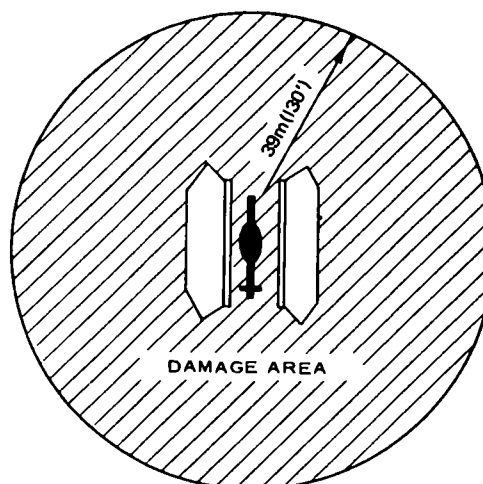
(1) A revetment 1.7 meters (5.5 ft) high will protect most of the helicopter's critical areas (turbine and transmission) against detonation at 9 meters (30 ft) range.

(2) A revetment 1.7 meters (5.5 ft) high will *not* protect the helicopter's critical areas (turbine and transmission) against detonation at 15 meters (50 ft) range.

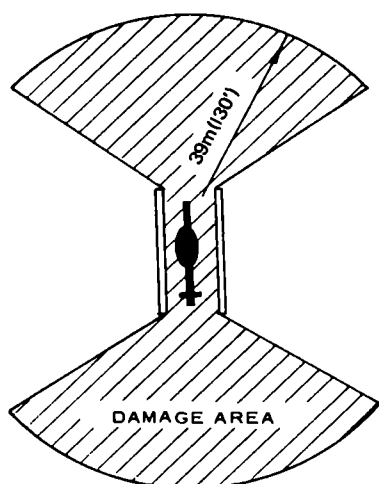
(3) A revetment either 2.7 meters (9 ft) or 3.6 meters (12 ft.) high will provide acceptable protection against detonation at 15 meters (50 ft) range.



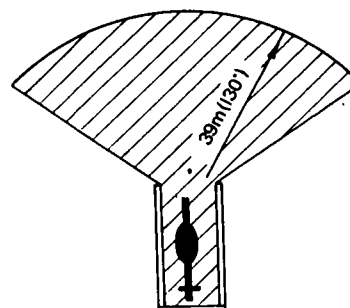
a. UNPROTECTED HELICOPTER



b. PARALLEL WALL REVETMENT
(50' x 25' x 5.5')
15m x 7.6m x 1.7m



c. PARALLEL WALL REVETMENT
(50' x 25' x 12')
15m x 7.6m x 3.6m



d. "U"-SHAPED REVETMENT
(50' x 25' x 12')
15m x 7.6m x 3.6m

Figure 5-1. Effectiveness of different revetment configurations against an 81 mm mortar.

5-3. Detailed Criteria

a. Revetment Dimensions. Inside dimensions of revetments to contain different types of Army aircraft are listed in table 5-1. The dimensions given provide limited clearances for moving or servicing the aircraft. As a rule, the area inside a revetment should be the minimum required to

be able to tow the aircraft into the revetment and provide for minimal movement and servicing. The inside area of the revetment should also provide for the largest aircraft of the several types in use. The inside dimensions of revetments required for Air Force aircraft should be coordinated with the Air Force.

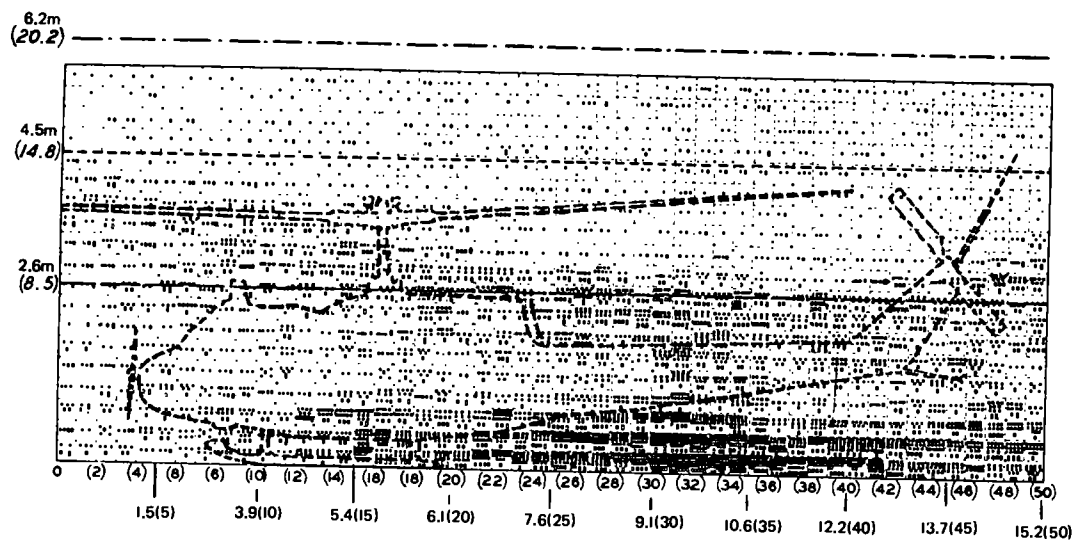
Table 5-1. Inside Dimensions of Revetments for Parked Army Aircraft

Dimensions—Meters(ft)										
Numerical	Name	Partial protection¹			Improved protection²			Full protection³		
		Width	Height	Length	Width	Height	Length	Width	Height	Length
		w	h	l	w	h	l	w	h	l
ROTARY WING										
OH-6A	Cayuse	6.2 (21)	1.2 (4)	12 (40)	6 (20)	2.4 (8)	12 (40)	11 (36)	3 (10)	13 (43)
OH-23	Raven	6 (20)	1.2 (4)	12 (40)	6 (20)	2 (7)	12 (40)	14 (46)	4 (13)	15.5 (51)
OH-58	Kiowa	6 (20)	1.2 (4)	12 (40)	6 (20)	1.83(6)	12 (40)	14 (46)	4 (13)	14 (46)
UH-1B/C	Iroquois	7.6 (25)	1.5 (4.8)	15 (49)	7.6 (25)	2.7 (9)	16 (52)	17.7 (58)	5 (16)	17.7 (58)
UH-1D/H	Iroquois	7.6 (25)	1.8 (5.5)	15 (49)	7.6 (25)	2.7 (9)	16 (52)	17.7 (58)	5 (16)	21 (68)
CH-34	Choctaw				6.7 (22)	3.7 (12)	17 (55)	20 (66)	5 (16)	23 (76)
CH-47	Chinook	7.6 (25)	2.7 (9)	17 (55)	7.6 (25)	4 (13)	18 (60)	21.4 (70)	6 (20)	18 (60)
CH-54	Flying Crane	10.7 (35)	3.4 (11)	24 (80)	10.7 (35)	5 (16)	27.4 (90)	25 (82)	6 (20)	27.4 (90)
AH-1G	Cobra	7.6 (25)	1.5 (4.8)	15 (49)	7.6 (25)	2.4 (8)	15 (49)	16.5 (54)	4.3 (14)	17 (55)
FIXED WING										
O-1	Bird Dog	13.4 (44)	2.4 (8)	9.5 (31)				14 (46)	33 (10)	11 (36)
OV-1	Mohawk	17 (56)	3.7 (12)	15 (49)				17 (56)	4.6 (15)	16 (52)
U-1	Otter	20 (66)	3.7 (12)	15 (49)				21 (68)	4.3 (14)	16 (52)
U-6	Beaver	17 (56)	3.7 (12)	11 (36)				17.7 (58)	3.7 (12)	12.5 (41)
U-8	Seminole	17 (56)	3.7 (12)	11 (36)				17 (56)	4.3 (14)	13 (43)
U-10	Helio-Courier	18.6 (61)	2.7 (9)	13 (43)				18.6 (61)	4.3 (14)	13 (43)
U-21 RU-21	UTE	17 (56)	3.7 (12)	11 (36)				17 (56)	5 (16)	14 (46)

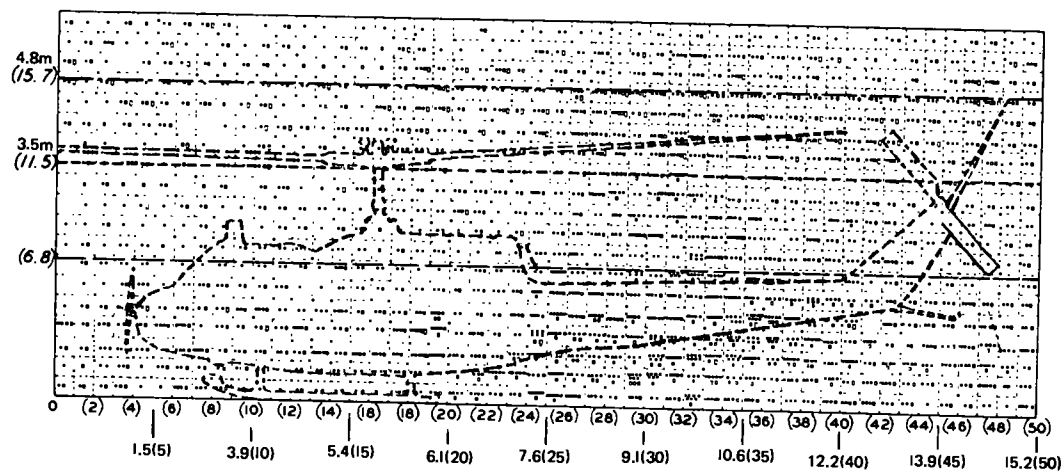
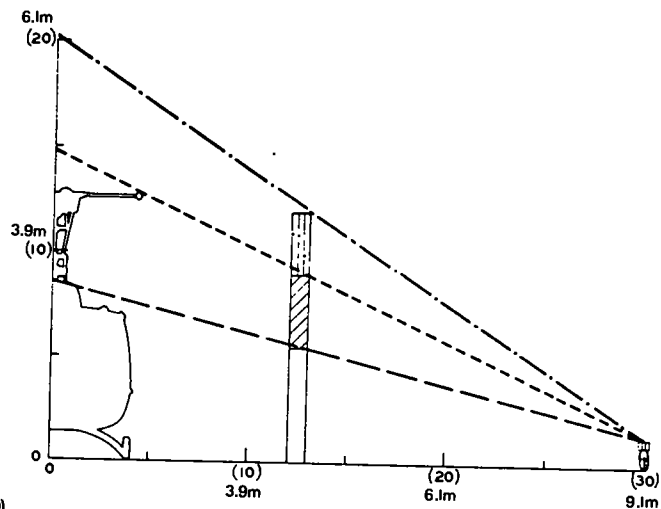
¹Partial Protection: These dimensions allow "fly in/fly out" capability for helicopters; however, engine compartments are exposed. These dimensions represent minimum size for fixed wing aircraft.

²Improved Protection: These sizes are recommended for maximum labor and material economy while providing maximum protection. Rotar blades of helicopters project over the walls.

³Full Protection: These dimensions inclose the entire aircraft. Although helicopter rotar blades are contained within the revetment, widths given for improved protection are more desirable.



DETONATION AT 9.1m (30-FT) RANGE



DETONATION AT 15.2m (50-FT) RANGE

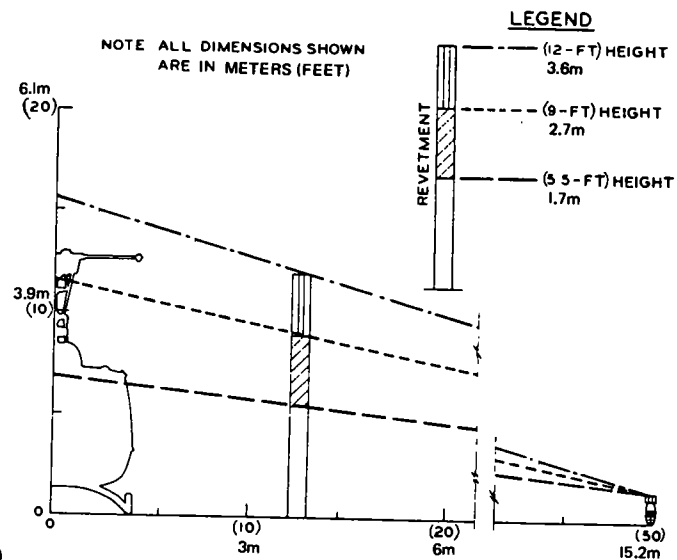


Figure 5-2. Amount of protection given by different revetment sizes against an 81mm mortar.

b. Propagation—Ammunition and Fuel.

(1) *Ammunition.* In addition to providing protection from hostile ground fire, revetments should also be arranged and spaced to minimize the explosive effects of bulk ammunition stored within the individual aircraft revetments or on the aircraft. Since a shell, grenade, or other explosive charge exploded near bulk quantities of ammunition normally will set off a chain reaction, fortifications should be provided to reduce these interacting explosive effects. Determination of ammunition effects involves an estimate of the equivalent explosive weight of the ammunition both on and near individual aircraft or within a proposed aircraft revetment area (table 5-2). The explosive weight of the hostile round should be included in the total explosive weight if it is a significant percent of the total explosive weight. The computed weight is then applied to the graph (fig 5-3) to determine a supposed safe distance, either with or without a protective barrier or wall between individual aircraft. Figure 5-4 provides a way of arranging the revetments to provide safe distances. It also indicates that two intervening walls are required between the protected aircraft and the explosive before any reduction in safe distance is obtained.

Table 5-2. Equivalent Explosive Weight Factors

Military munitions	Equivalent Explosive weight factors
Shells—all types	0.70
Rockets	.70
Grenades	.70
Small arms (ball and AP ammo)	.40
Military explosives	
TNT	1.00
Composition C-4	1.30
Sheet explosive	1.30
Tetrytol	1.20
Ammonium nitrate	.50
Military dynamite	1.00

Note. Multiply the above factors by the estimated weight of the ammunition to derive equivalent explosive weight.

(2) *Fuel.* The destructive force of exploding fuel is considerably less than the force resulting from exploding ammunition. Protective measures against ammunition having an explosive weight of 45kg (100lb) or more will also provide protection from fuel explosions in the same area. The distance between aircraft should be not less than 25m (82 ft) when there are two

intervening walls, nor less than 45m (150 ft) when there are less than two walls, if ammunition or fuel is present. The floor of the revetment should be designed with a slope to control the direction of flow of spilled burning fuel. If burning fuel should flow under other aircraft, the heat could result in additional explosions.

c. Estimation of Weapons' Effects. The initial investigation should disclose the types of ammunition against which protection is required, based on field experience in a particular area. The effects of ammunition in common use should be considered with relation to soil conditions or moisture content, since high velocity ammunition has somewhat more penetration effect against wet or damp soil than it has against dry material. Other factors being equal, protection should be provided against the type of ammunition having the greatest penetration potential (table 1-1 and app B).

d. Design Factors. Essential factors in revetment design are the most effective type of ammunition in common use and the resistance of the protective material available for revetment purposes. The relationship between these two factors has been reduced to a penetration resistance factor, previously defined. A factor of 1.00 provides the theoretical minimum thickness of a given material to resist penetration by the types of ammunition shown in the graphs (app B) under the three construction conditions considered.

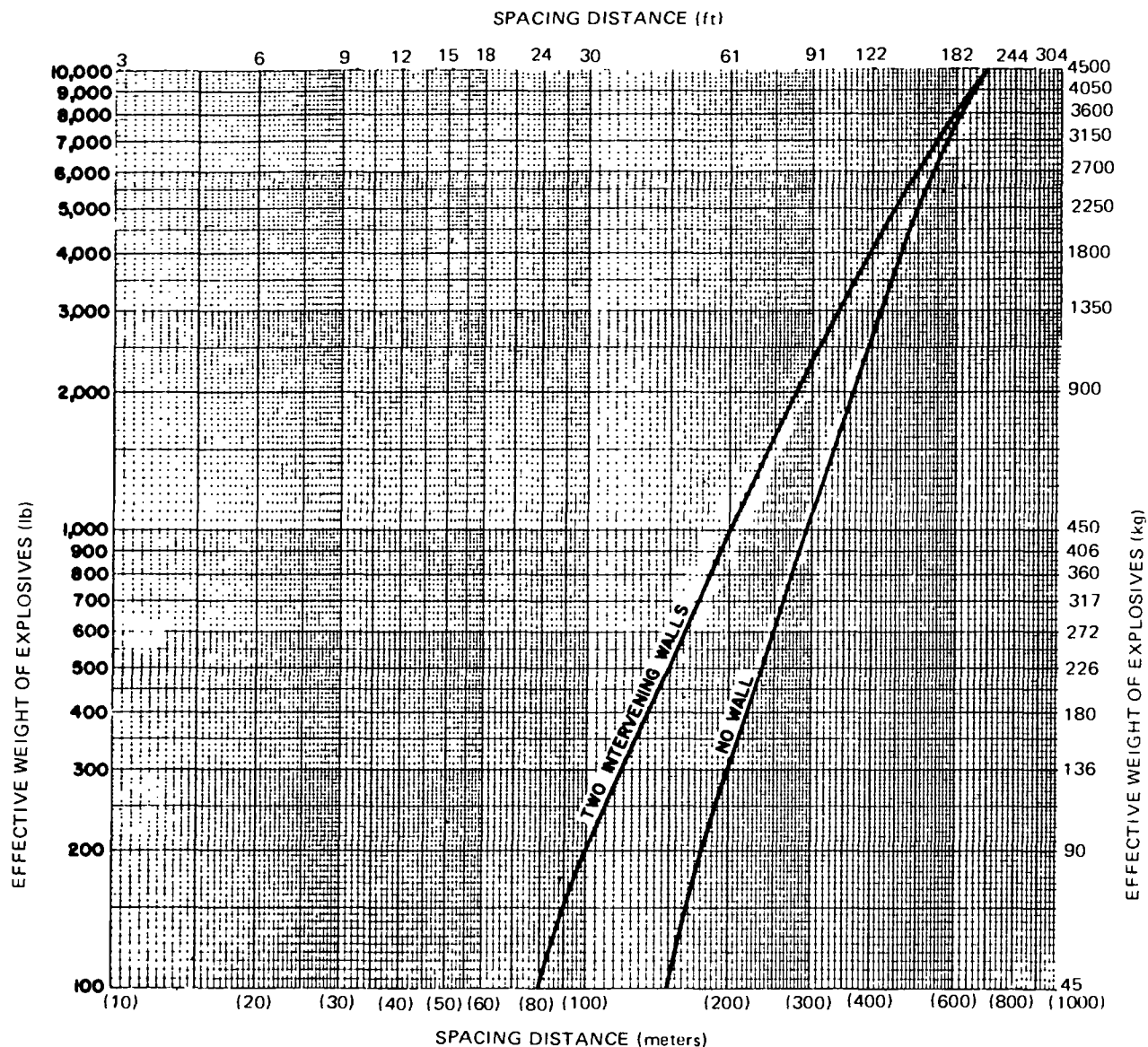
e. Selection of Materials. If a choice of materials, including timber or steel in suitable form and several types of soil, is available, the selection involves consideration of the protective characteristics of the different materials or a combination of the available materials which will resist penetration by the most effective type of ammunition which may be used. Handling methods, appropriate equipment, and labor skills will also influence the selection of materials as will the type of revetment being constructed. Quantities of materials required for different types of revetments can be estimated from table 5-3.

f. Cross-section Configuration of Revetments. The type and pattern of the revetments to be constructed should reflect planning for protection against the weapons in use.

g. Spacing Between Revetments. Revetment spacing should provide an arrangement of individual aircraft protective structures which will

(Located in back of Manual)

Table 5-3. Estimating Materials for 3-meter (10 ft) Sections of Revetments.



CENTER TO CENTER REVETMENT

Figure 5-3. Safe distance with or without protective barrier.

allow ready access to the aircraft for efficient servicing, maintenance, and tactical operations. Anticipated active defense measures for the area should also be considered.

h. Dispersal Methods. Dispersal of aircraft depends primarily on the available area and will vary from one field to another. Ideally, dispersal will separate the aircraft enough to minimize the danger of interacting ammunition and fuel explosions. The method used should avoid, so far as is possible, any consistent pattern that will aid adjustment of high angle fire on the aircraft. Dispersal areas are illustrated in the conceptual layouts shown in figures 3-1 through 3-5 and discussed in paragraph 3-1.

5-4. Sample Revetment Design

A sample revetment design under assumed conditions is included to illustrate the use of the information and criteria discussed above.

a. Requirement: Revetments for 10 aircraft, type UH-1D, providing maximum protection possible with available materials. *Given:*

- (1) Known weapons in use:
 - .50 cal. machineguns
 - 90mm recoilless rifles
 - 60mm mortars
- (2) Available materials:
 - 5cm (2-in) sheathing—1115 sq meters (12,000 sq ft) (retaining wall)
 - 5 × 10cm (2 in × 4 in)—4267 meters

(14,000 linear feet) (vertical supports)

Accessory materials including wire cable, clamps, nails, bolts, etc. (unlimited)

Dry sand for filler (unlimited)

(3) Aircraft armament:

7.62mm ammunition—45kg (100 lb)

Rockets—90kg (200 lb)

b. Preliminary Revetment Design: Gravity revetment (condition I—no standoff) to provide full lateral protection (fig 5-5 and 5-7).

(1) Inside dimensions of protective structure for UH-1D aircraft from table 5-1:

W = 17.7m (58 ft)

L = 21m (68 ft)

H = 5m (16 ft)

(2) An estimate of required materials may be made by using table 5-3.

Materials available after computation of waste factor:

Sheathing—20 percent waste factor = 80 percent usable material 0.80×1115 sq meters = 892 sq meters $0.80 \times 12,000$ sq ft = 9,600 sq ft).

Vertical supports—10 percent waste factor = 90 percent usable material 0.90×4267 m = 3840m ($0.90 \times 14,000$ linear ft = 12,600 linear ft).

(3) Linear meters (feet) of sheathing required for retaining wall:

$(W + 2L) \times \text{number of aircraft} = (17.7 + 2 \times 21) \times 10 = 597$ linear meters $(58 + 2 \times 68) \times 10 = 1,940$ linear feet) or 194 three-meter (10-foot) sections.

(4) Sheathing area for gravity revetments:

3H per 3 meter section = $(3 \times 5) \times 194 = 2910$ sq meters (10H per-10-foot section = $(10 \times 16) \times 194 = 31,040$ square ft).

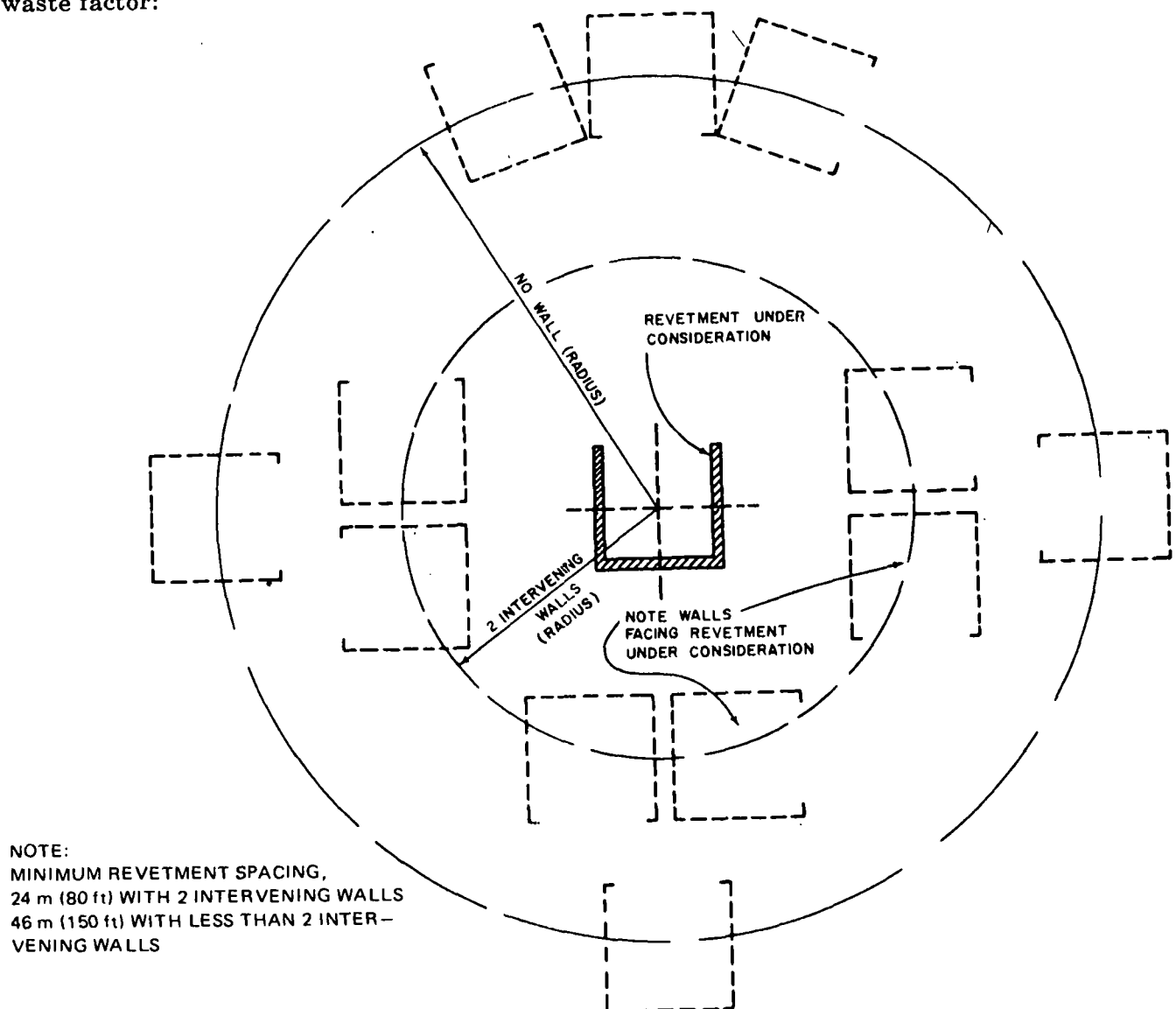
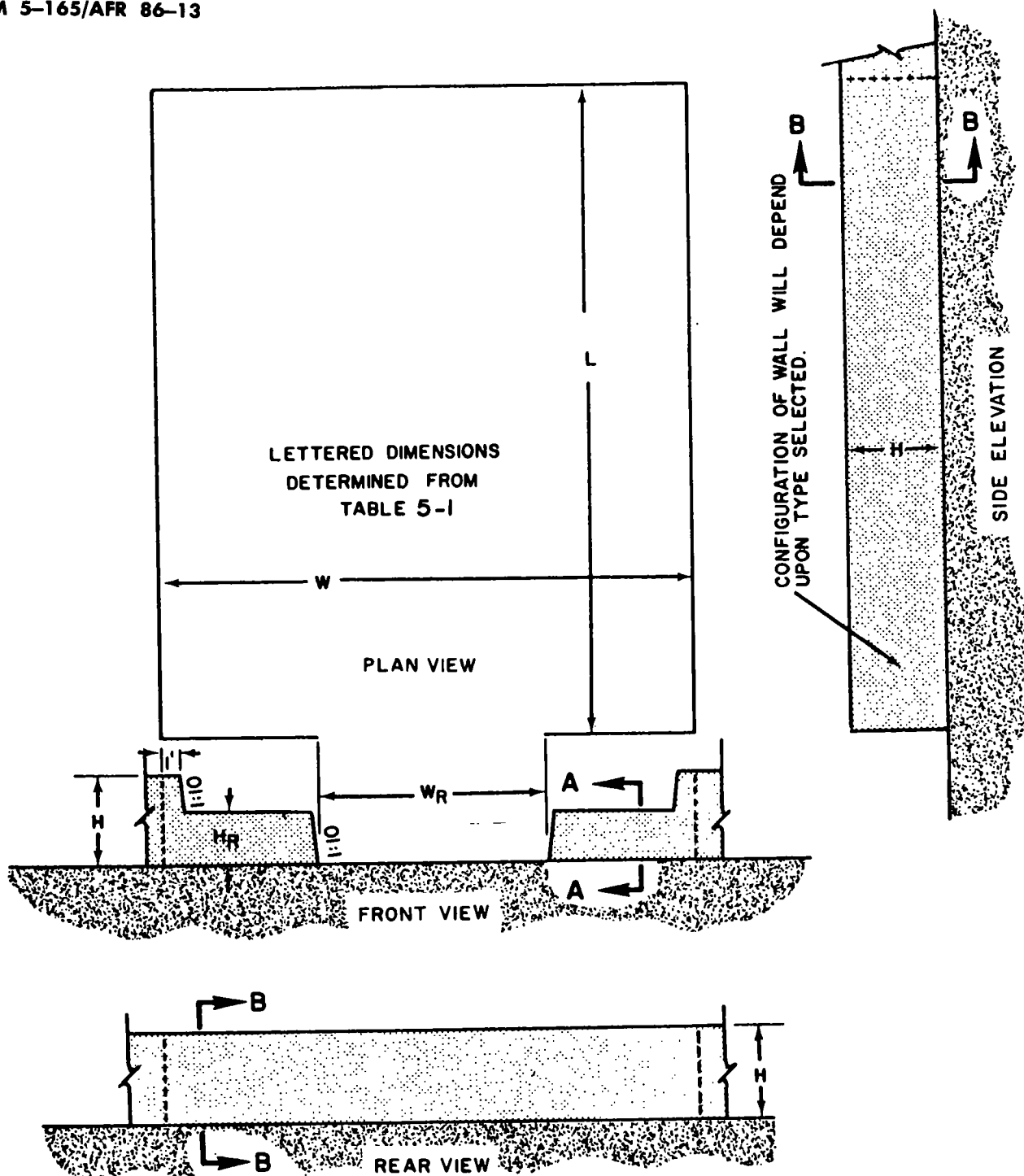


Figure 5-4. Orientation of revetments to provide safe distances.



EXACT WALL CONFIGURATION DEPENDENT UPON TYPE SELECTED
SECTION AA SHALL BE PROPORTIONAL TO SECTION BB

Figure 5-5. Plan view, rotary wing—full lateral protection.

Note. Since the amount of sheathing required for this type of protection exceeds the amount available, the design must be adjusted accordingly. Partial lateral protec-

tion (fig 5-6) is one possibility. This will provide protection for each side of the aircraft, leaving the ends of the fortification open.

c. *Revised Revetment Design*: Dimensions from table 5-1:

$W = NA$ (For computation of materials—open ended)

$L = 16\text{m}$ (52 ft)

$H = 2.7\text{m}$ (9 ft)

(1) Repeating computation shown for preliminary design—gravity revetment, condition I:

Linear meters (feet) of sheathing required: $2 \times 16 \times 10 = 320$ linear meters ($2 \times 52 \times 10 = 1,040$ linear feet) or 107 three-meter sections or 104 ten-foot sections.

Note. Converting from feet to meters round up to provide a safety factor.

(2) Sheathing area:

$3H$ per 3m section— $(3 \times 2.7) \times 107 = 867$ sq meter

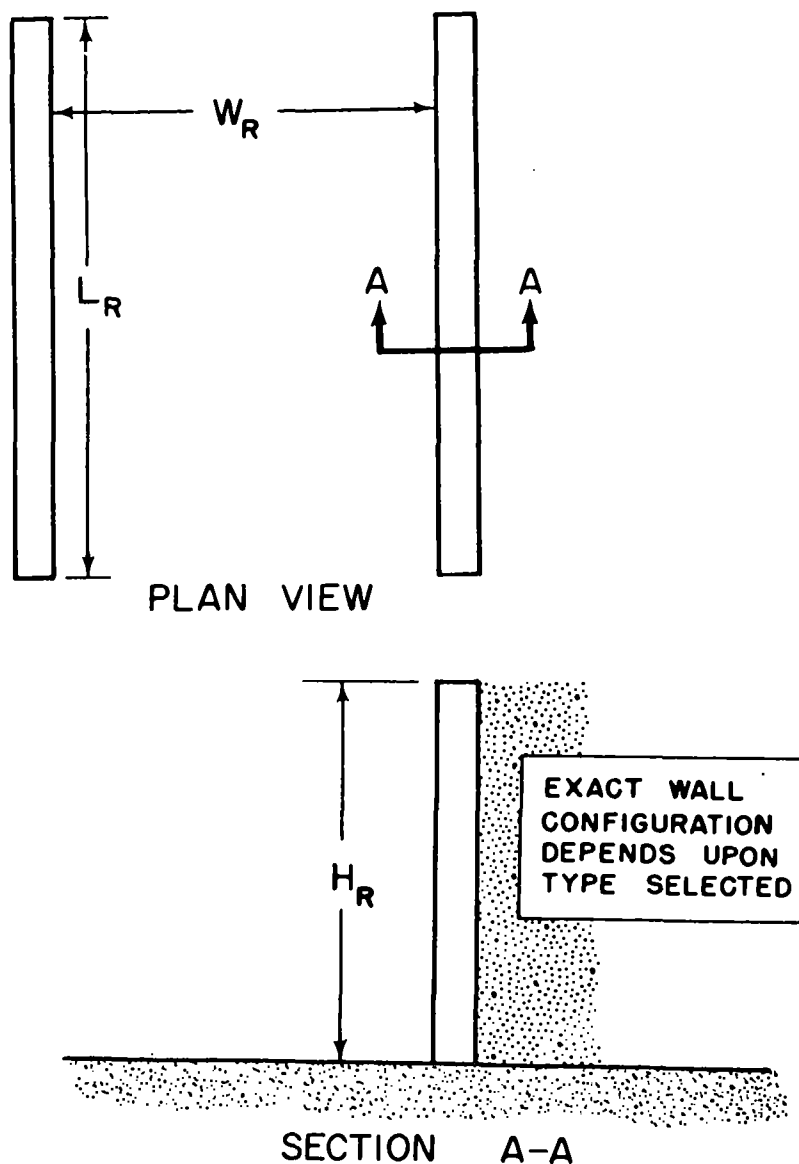
$(10H)$ per 10-foot section = $(10 \times 9) \times 104 = 9,360$ sq ft.)

(3) Vertical supports:

$11(H + .6)$ per 3-meter section = $11(2.7 + .6) \times 107 = 3,884$ linear meters.

$(11(H + 2))$ per 10-foot section = $11(9 + 2) \times 104 = 12,584$ linear feet).

(4) Thickness of protective material: Use PRF of 1.00 (table 1-1 or fig B-1,) for 90mm ammunition, the most effective type, which requires 107 cm (42 in) of dry sand for penetration resistance. Round off to nearest 0.1 meter (foot). Therefore: $T =$ thickness of 1.1 meter (4 feet).



© Rotary wing—partial lateral protection

Figure 5-6. Plan view, rotary wing—partial lateral protection.

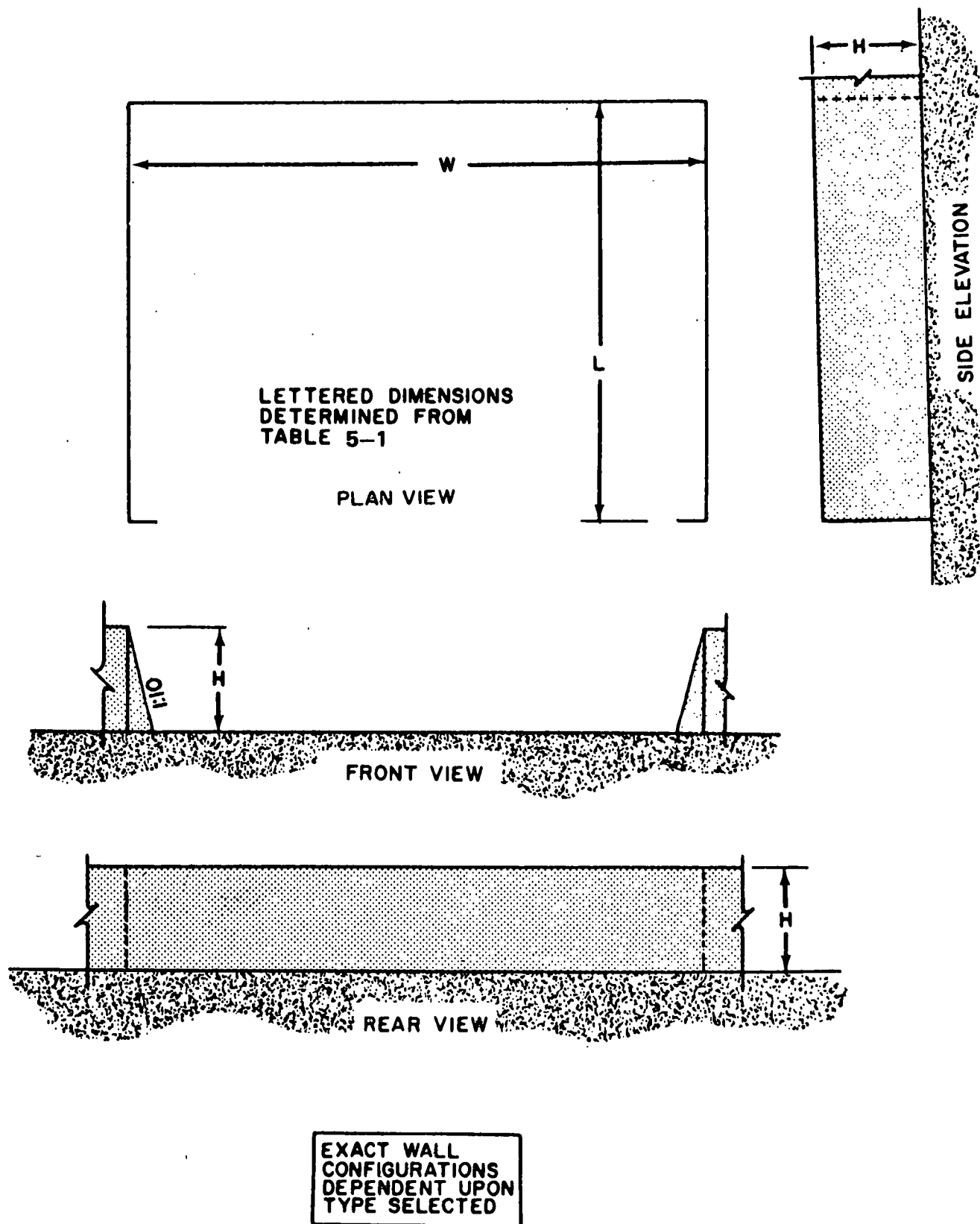


Figure 5-7. Plan view, fixed wing.

(5) Filler material: $3.05 \left(t \times H + \frac{H^2}{2} \right)$ per

3-meter section =

$$3.05 \left(1.22 \times 2.74 + \frac{2.74^2}{2} \right) 107 = 2320 \text{ cu meters}$$

$$0.4 \left(T \times H + \frac{H^2}{2} \right) \text{ per 10-foot section} =$$

$$(0.4 (4 \times 9 + \frac{9^2}{2}) 104 = 3,182 \text{ cubic yards.})$$

d. Spacing of Revetments.

(1) Total equivalent weight of explosives (table 5-2):

7.62 mm—45 = 0.40 =	-----	=	18 kg
(100 × 0.40 =	-----	=	40 lb)
Rockets—90 × 0.70 =	-----	=	63 kg
(200 × 0.70 =	-----	=	140 lb)
			81 kg
			(180 lb)

Section II. DESIGN OF THIN-WALLED REVETMENTS

5-5. Introduction

Thin-walled revetments have been developed for attack, utility, and cargo-type helicopters. These revetments consist of plywood or corrugated metal walls containing a 30cm (12 in) thick soil fill. Thin-walled revetments may be either post-supported or free standing. Post-supported revetments can use either timber or pipe as support. Post-supported revetments are designed primarily for cargo-type helicopters (CH-47, CH-54). Free-standing revetments are designed for use with utility or attack helicopters. In short, thin-walled (30cm (12-in) thick) revetments require less fill material than thick-walled (1.2m (4 ft) or more) revetments, less space, less equipment, and less construction time. Paragraphs 5-6 and 5-7 contain information on post-supported revetments and paragraph 5-8 a discussion of free-standing revetments.

5-6. Post-Supported Revetments

a. Illustrations. Figures 5-8 through 5-14 illustrate various designs of thin-walled revetments. The heights of the revetments presented are restricted by the "fly in/fly out" capability. Refer to paragraphs 1-12 and 5-2 for a general discussion of revetment height prior to selecting final designs for a specific application.

b. M8A1 Landing Mat Revetment Supported by Timber Post. Figures 5-8, 5-9, and 5-10 show revetment specifications for the UH-1, the CH-47, and the CH-54 helicopters.

(2) Spacing: Enter vertical scale of graph (fig 5-3) opposite 81 kg (180 lb), then proceed horizontally to intersection of curves and read on the horizontal scale:

30m (98 feet)—intervening walls

52m (170 feet)—no walls between aircraft

e. Final Design Type and Dimensions:

(1) Gravity revetment, dimensioned timber:
Sheathing—Height—2.7m (9 ft)

Length—16m (52 ft)

(2) Protective material—

Thickness—1.2m (48 in) Top

—3.35m (11 ft) base, assuming
45° angle of repose for sand.

(3) Revetment spacing—

30m (98 ft)—intervening walls

52m (170 ft)—no walls between aircraft

c. M8A1 Landing Mat Revetment Supported by Pipe Posts. Figures 5-11 and 5-12 show the revetment specifications for the CH-47 and the CH-54 helicopters.

d. Plywood or Corrugated Metal Revetments. Figures 5-13 and 5-14 show the revetment specifications for the CH-47 and the CH-54 helicopters.

5-7. Construction of Post Supported Revetments

The following points should be kept in mind when constructing all post-supported revetments:

a. Postholes. Holes for both timber and pipe posts should be as large as practical. By employing a truck-mounted hole borer with a 55cm (22 in) diameter bit, alinement will be much easier to achieve.

b. Depth of Post (table 5-4).

(1) Use the maximum depth given in table 5-4 for post in soil or concrete if soil properties are unknown.

(2) For larger revetments of 2.7 and 3.3 meters (9 ft and 11 ft) the horizontal bearing area should be increased by attaching 5 × 30cm (2 × 12 in) lumber (or larger to both 15cm (6-in) dimensions of the 15 × 30cm (6 × 12in) timber posts. These attachments should extend from the ground surface to the bottom of the posts. Ideally, if the horizontal bearing area is increased, the stabilization of the posts will be improved by 25 percent.

c. *Installation of Walls.*

(1) M8A1 landing mat panels should be assembled on the ground near the work site. As the panels are put together to the desired height

the entire 3.66m (12-ft) section can be lifted as a unit by using a wrecker or crane. The panels will not come unlocked if they are moved carefully to the wall.

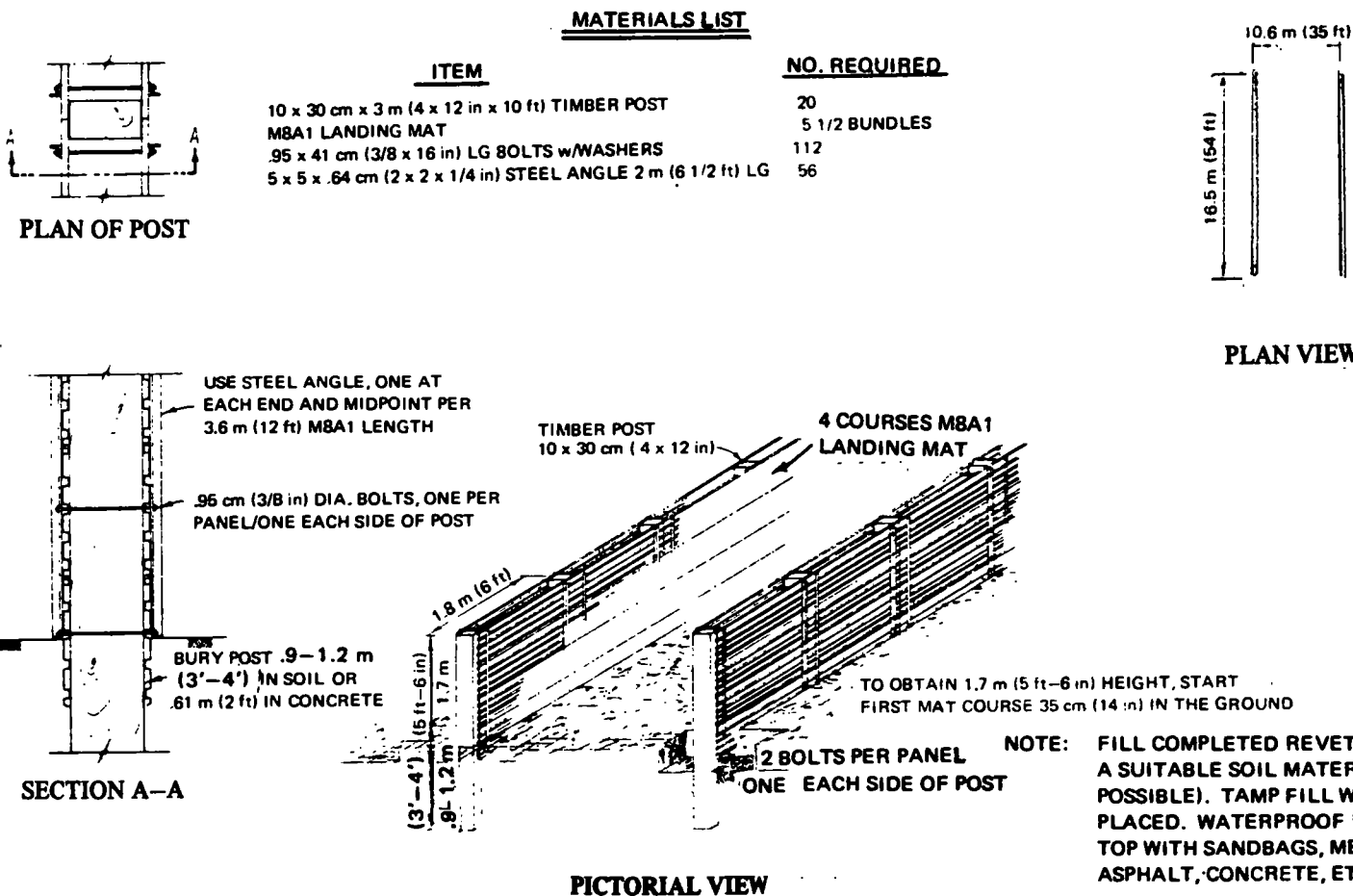
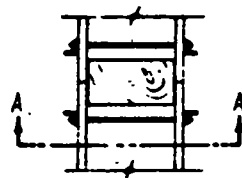


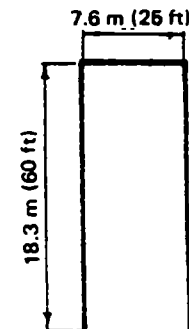
Figure 5-8. M8A1 landing mat with timber post supports (soil filled revetment for UH-1 helicopter).



PLAN OF POST

MATERIALS LIST

ITEM	NO. REQUIRED
15 x 30 cm x 4.2 m (6 x 12 in x 14 ft) TIMBER POST	29
M8A1 LANDING MAT	11 BUNDLES
.95 x 43 cm (3/8 x 17 in) LG BOLTS w/WASHERS	216
5 x 5 x .64 cm (2 x 2 x 1/4 in) STEEL ANGLE 2.7 m (9 ft) LG	72
5 x 30 cm x 2.4 m (2 x 12 in x 8 ft) TIMBER BEARING PLATE	29



PLAN VIEW

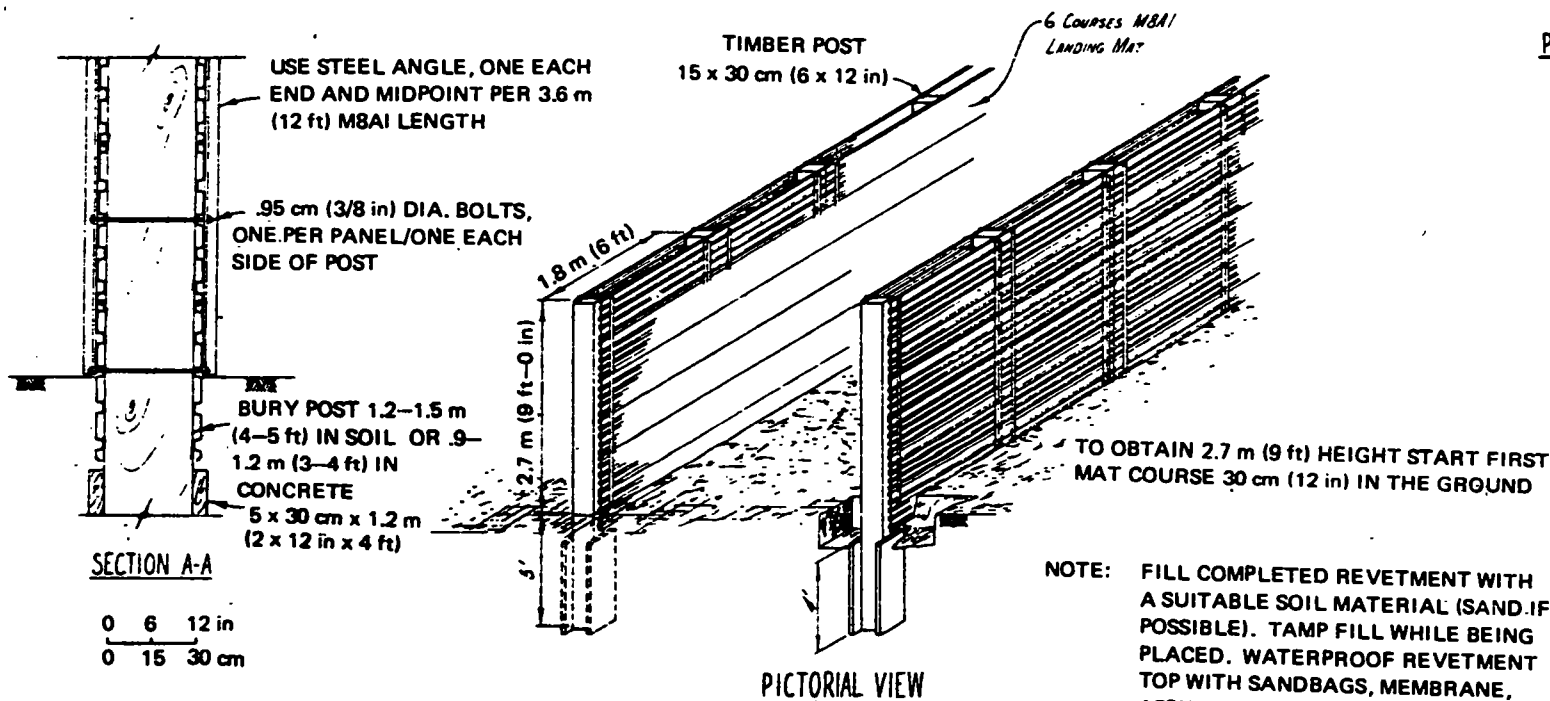


Figure 5-9. M8A1 landing mat with timber post supports (soil filled revetment for CH-47 helicopter).

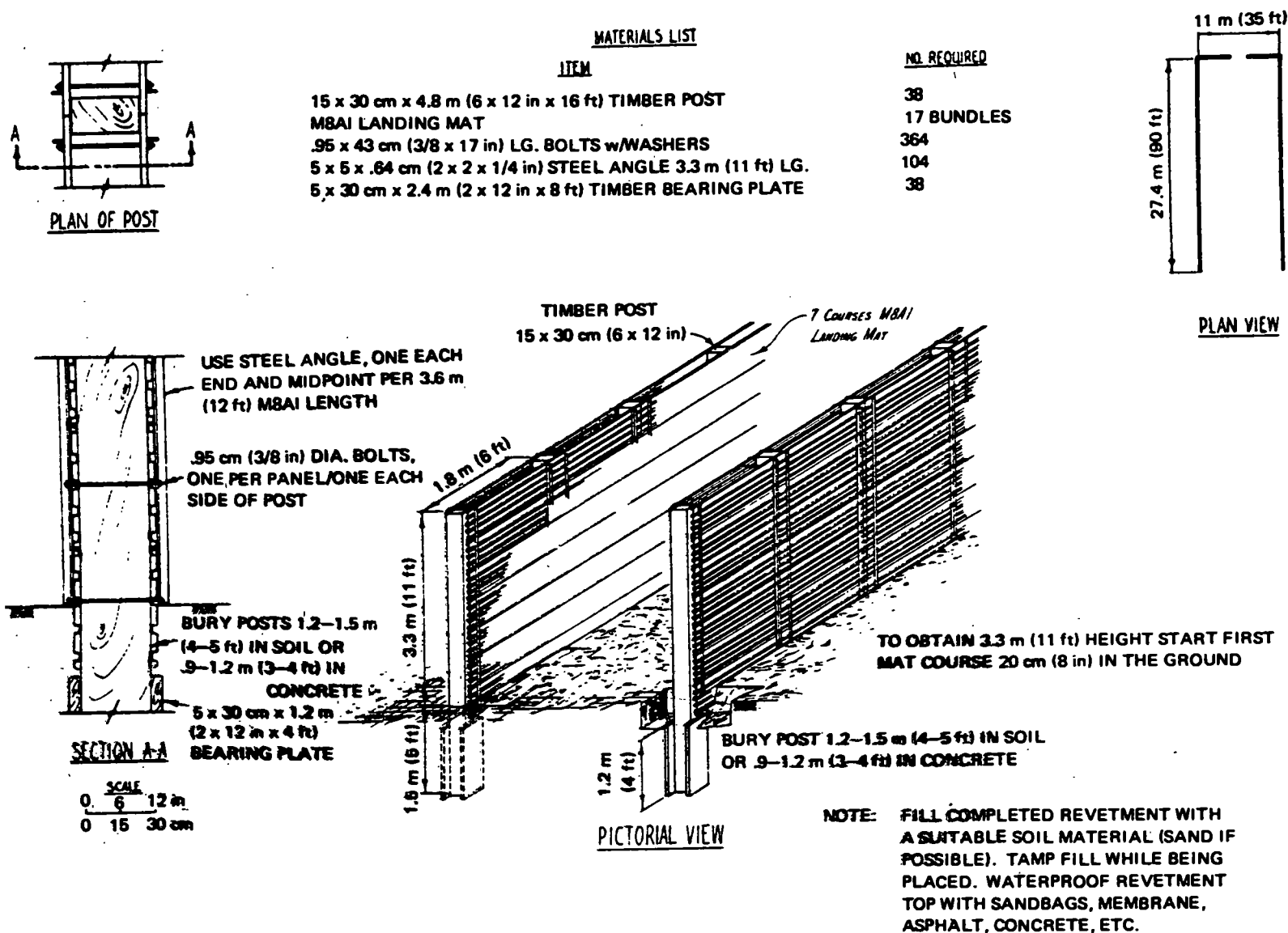


Figure 5-10. M8A1 landing mat with timber post supports (soil filled revetment for CH-54 helicopter).



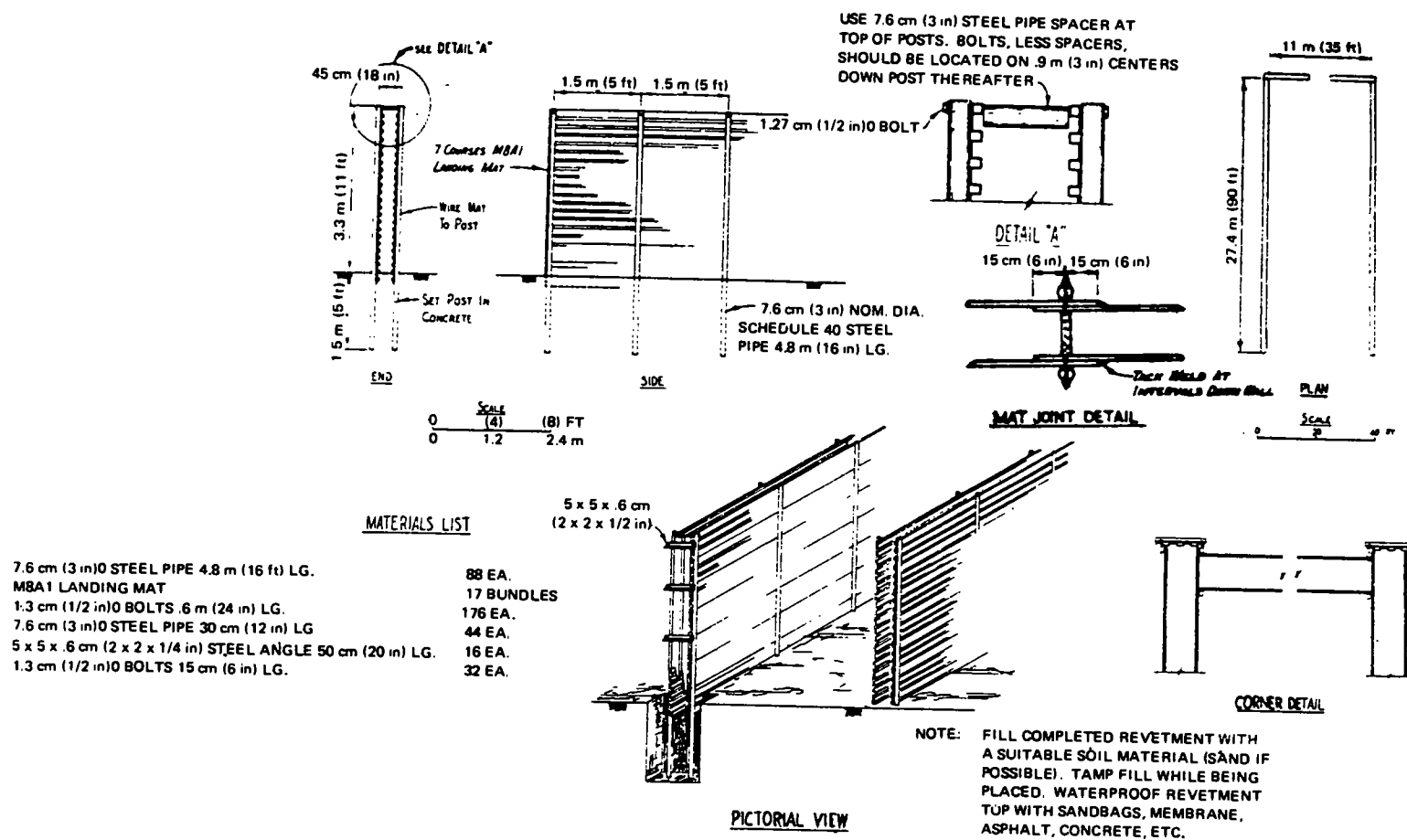
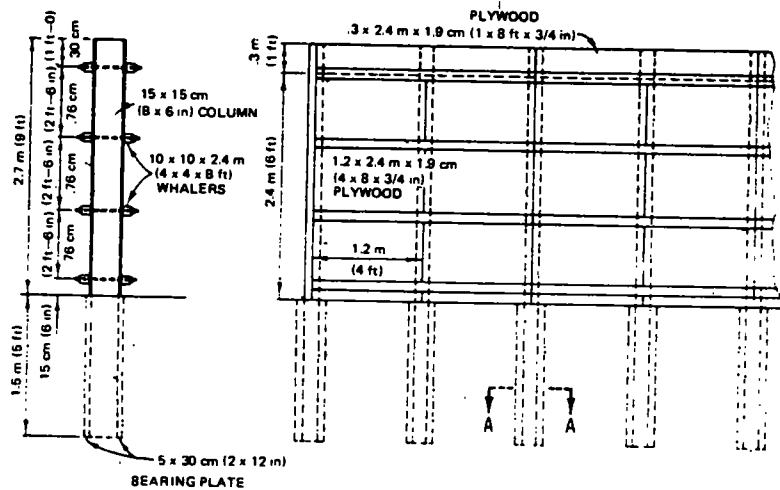
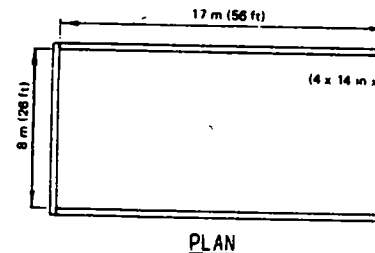


Figure 5-12. M8A1 landing mat with pipe post supports (soil filled revetment for CH-54 helicopter).

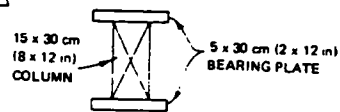


FRONT ELEVATION

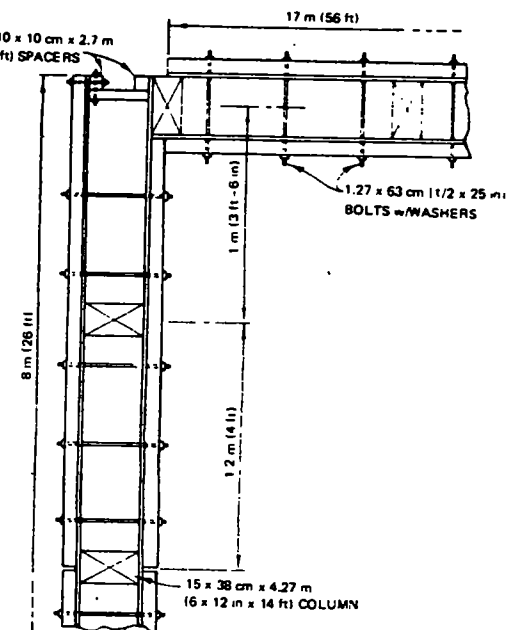
SIDE ELEVATION



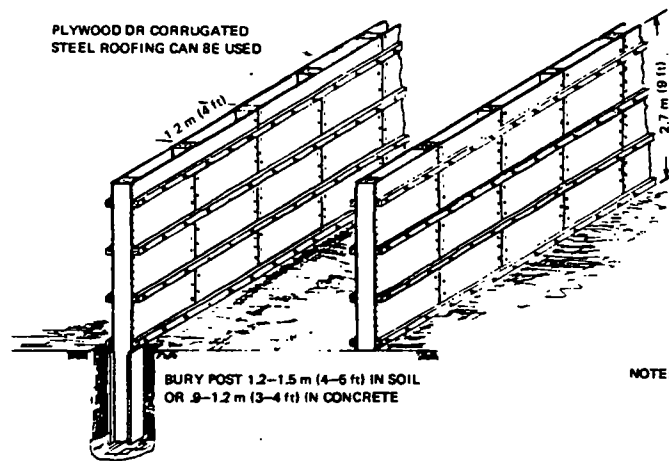
PLAN



SECTION A-A



CORNER DETAIL



PICTORIAL VIEW

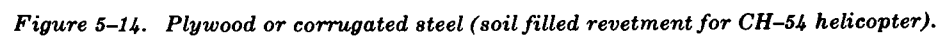
MATERIALS LIST

1.2 x 2.4 x 1.9 cm (4 x 8 ft x 3/4 in) PLYWOOD OR STEEL ROOFING
 10 x 10 cm x 2.4 m (4 x 4 in x 8 ft) WHALERS
 63 x 1.27 cm (25 x 1/2 in) BOLTS w/WASHERS
 15 x 30 cm x 4.27 m (6 x 12 in x 14 ft) POSTS
 5 x 30 cm x 3 m (2 x 12 in x 10 ft) BEARING PLATE
 10 x 10 cm x 2.74 m (4 x 4 in x 9 ft) SPACERS

74 SHEETS-
 144 PIECES
 420 EA.
 38 EA.
 38 EA.
 4 EA.

NOTE: FILL COMPLETED REVETMENT WITH A SUITABLE SOIL MATERIAL (SAND IF POSSIBLE). TAMP FILL WHILE BEING PLACED. WATERPROOF REVETMENT TOP WITH SANDBAGS, MEMBRANE, ASPHALT, CONCRETE, ETC.

Figure 5-13. Plywood or corrugated steel (soil filled revetment for CH-47 helicopters).



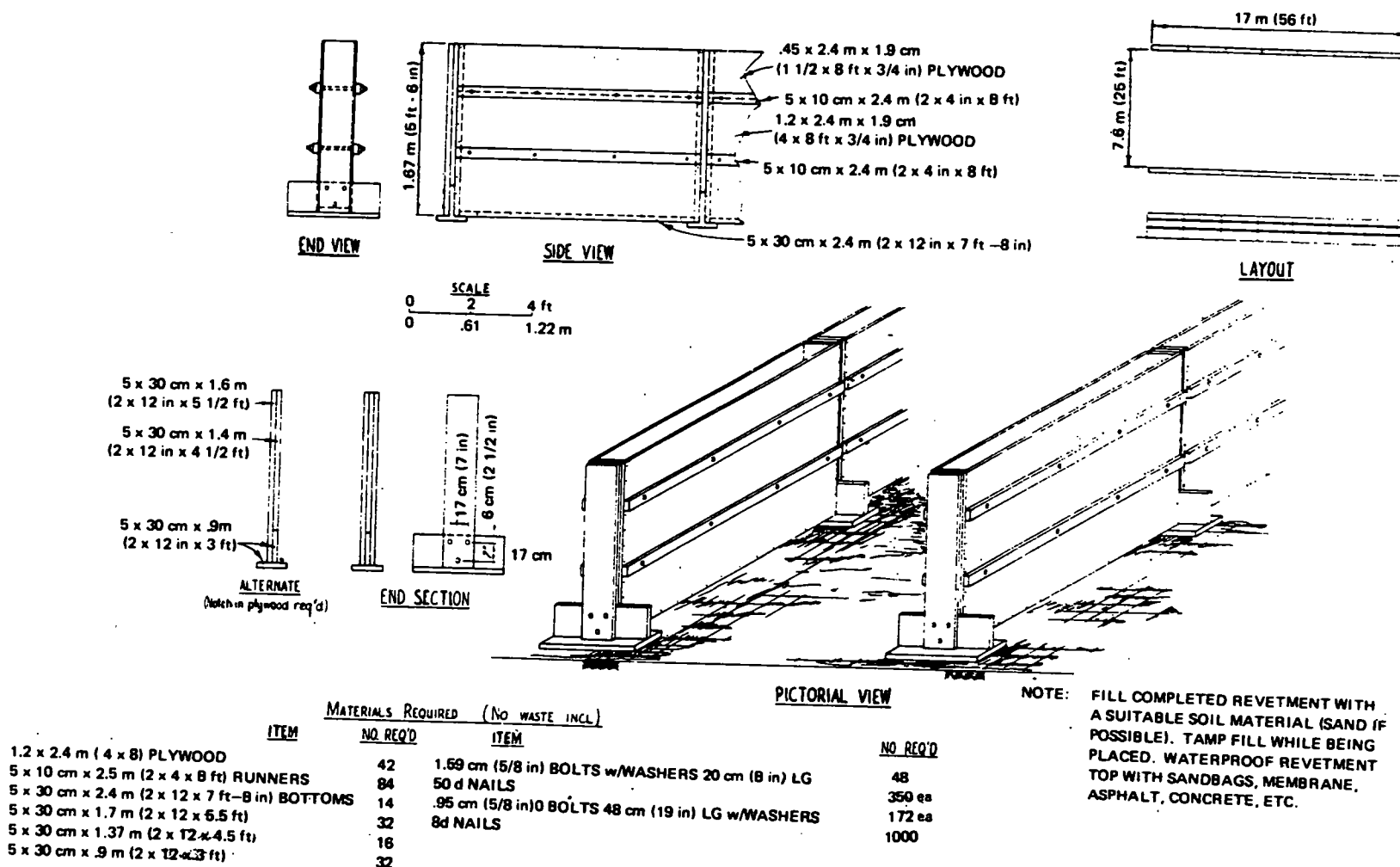


Figure 5-15. Free-standing plywood (soil filled revetment for UH-1 helicopter).

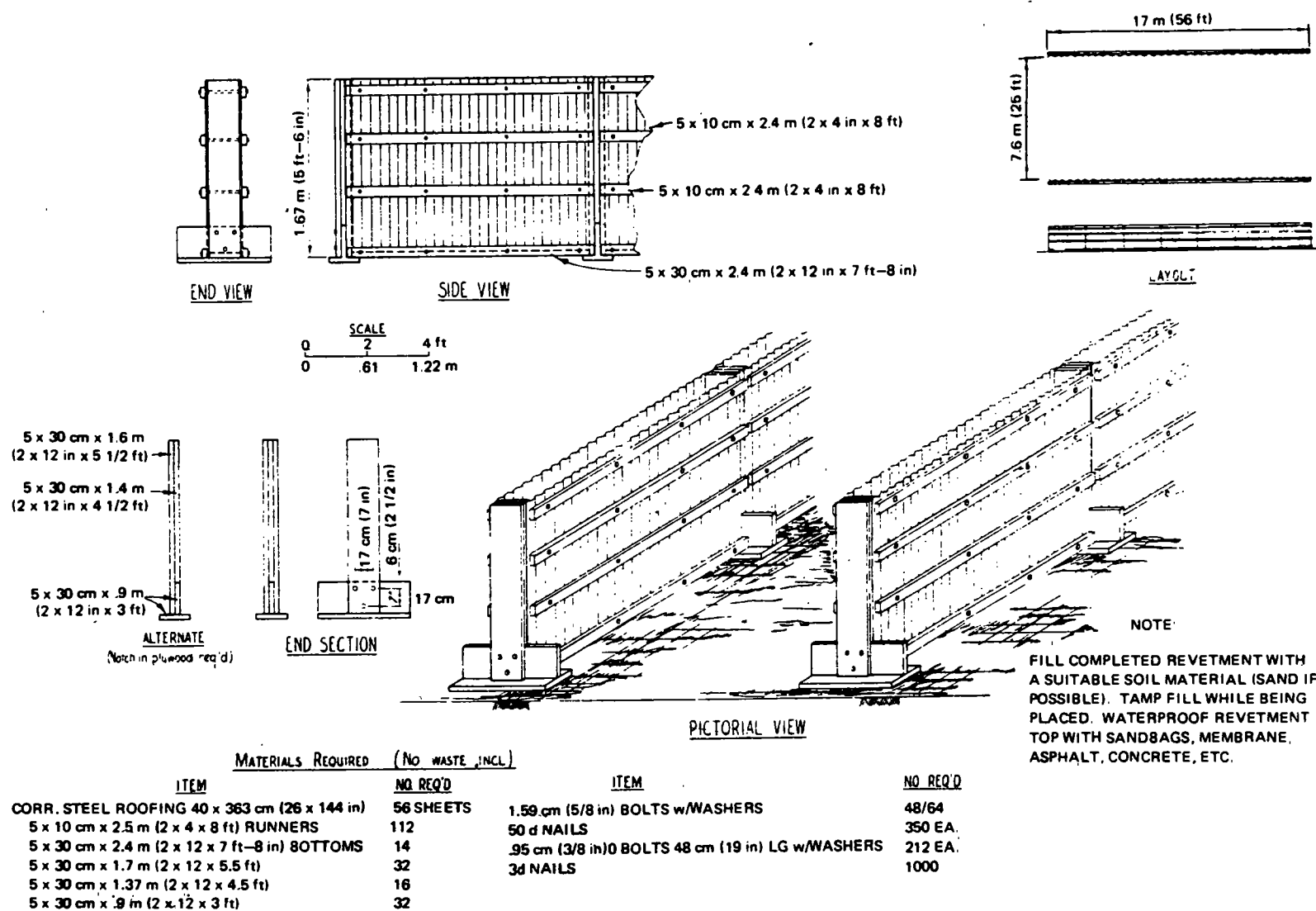


Figure 5-16. Free-standing corrugated steel (soil filled revetment for UH-1 helicopter).

Table 5-4. Depth of Posts

Revetment height	Depth of posts	
	Soil	Concrete
1.67m (5.5 ft)	.9 to 1.2m (3 to 4 ft)	.6m (2 ft)
2.74m (9 ft)	1.2 to 1.5m (4 to 5 ft)	.9 to 1.2m (3 to 4 ft)
3.35m (11 ft)	1.2 to 1.5m (4 to 5 ft)	.9 to 1.2m (3 to 4 ft)

(2) The plywood and corrugated metal wall revetment materials and horizontal braces should be predrilled on the ground and then attached to the posts.

d. Fill Material. A scoop loader is ideally suited for fill placement. Dry sand is the most desirable fill material. While placing the material, periodic tamping of the fill material will help to eliminate air pockets and improve its resistance to fragment penetration.

e. Waterproofing. In order to minimize the moisture content, each completed revetment should be capped with membrane, asphalt, concrete, roofing paper, sandbags filled with a soil-

cement mixture, or some other waterproofing material.

5-8. Free-Standing Revetments

a. Free-Standing Plywood Revetment. Figure 5-15 gives design specifications for the free-standing plywood revetment.

b. Free-Standing Corrugated Steel Revetment. Figure 5-16 gives design specifications for the free-standing corrugated steel revetment.

c. Anchorage.

(1) On ground surfaces, any one of the following items may be used to anchor free-standing revetments: arrowhead anchors, screw-type anchors, steel pickets, and wooden or steel stakes.

(2) On concrete or landing mat surfaces, the revetments should be braced or the footings secured with weights.

d. Height. Safety precautions limit the height of free-standing revetments to a maximum of 1.8m (6ft).

Section III. PREFABRICATED MOVABLE REVETMENTS

5-9. Introduction

Two types of ready-made movable revetments are the precast concrete unit and the mobile M8A1 revetment.

a. The precast concrete units are high in permanency, low in troop cost, easy to repair, and relocatable.

b. The mobile M8A1 revetment is used primarily to close off U-shaped revetments for the CH-54 helicopter. It requires less construction effort than the precast concrete unit, but does not offer 100 percent protection against shrapnel.

5-10. Movable Precast Concrete Units

a. A primary use for precast concrete revetments is for the protection of aircraft. They can be emplaced by engineer troops or other organizations using a crane and can be relocated.

b. The physical characteristics of the precast concrete units are variable. The height of the

units can be from 1.2 to 3.66m (4 to 12 ft). The width varies with the height of the unit; however, the maximum width at the base of the concrete unit is 1.67m (5.5 ft). The length of the precast unit is 2.44m (8 ft) for heights up to and including 2.74 (9 ft). It should be noted that rotor strike occurs on the UH-1 if this type of revetment is higher than 1.67m (5.5 ft).

c. Figures 5-17 and 5-18 illustrate two types of relocatable precast concrete revetments.

5-11. Mobile M8A1 Revetments

a. The mobile M8A1 revetment can be fabricated by engineer troops or by other organizations. Individual units of the revetment may be connected by chain and can be filled by hand with earth.

b. The mobile M8A1 is 3.55m (11 ft 8 in) high.

c. Table 5-5 gives the bill of materials for one mobile M8A1 revetment.

d. Figure 5-19 illustrates this revetment.

REVETMENT

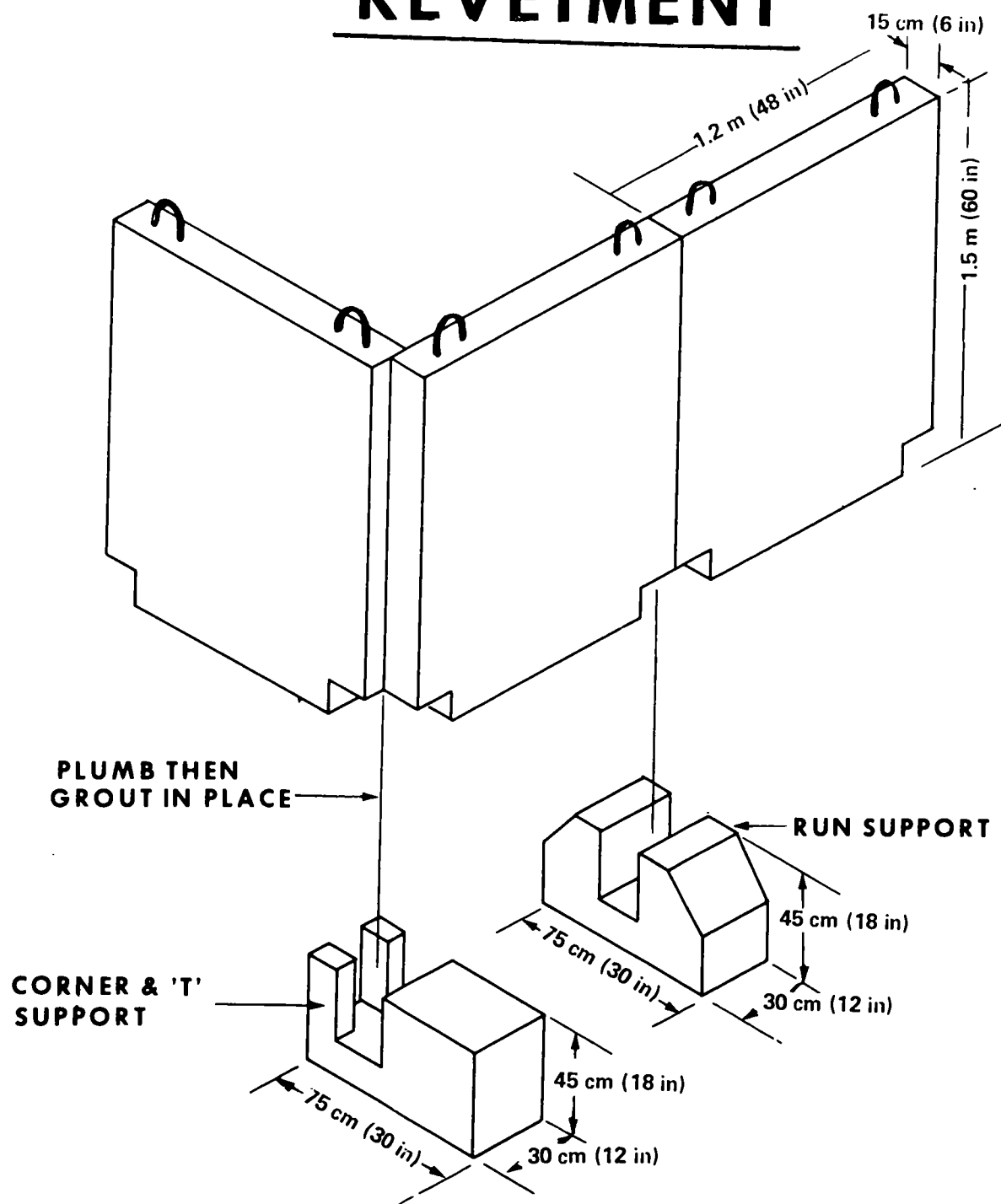


Figure 5-17. Precast concrete revetment (relocatable 1.5 to 2.9 m (5 to 9.5 ft) high sections).

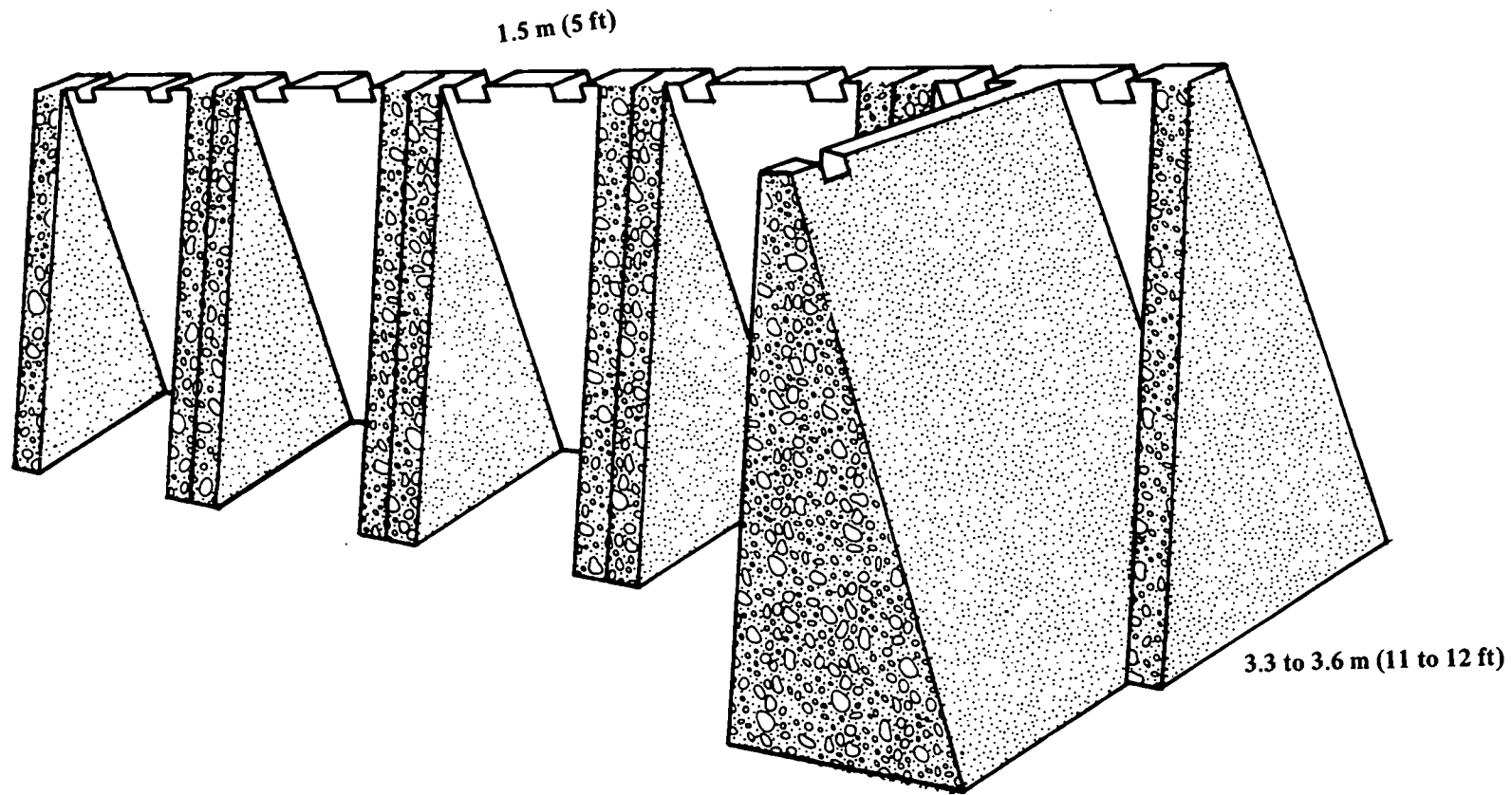


Figure 5-18. Precast concrete revetment (relocatable 3.35m and 3.66m (11 to 12 ft) high sections).

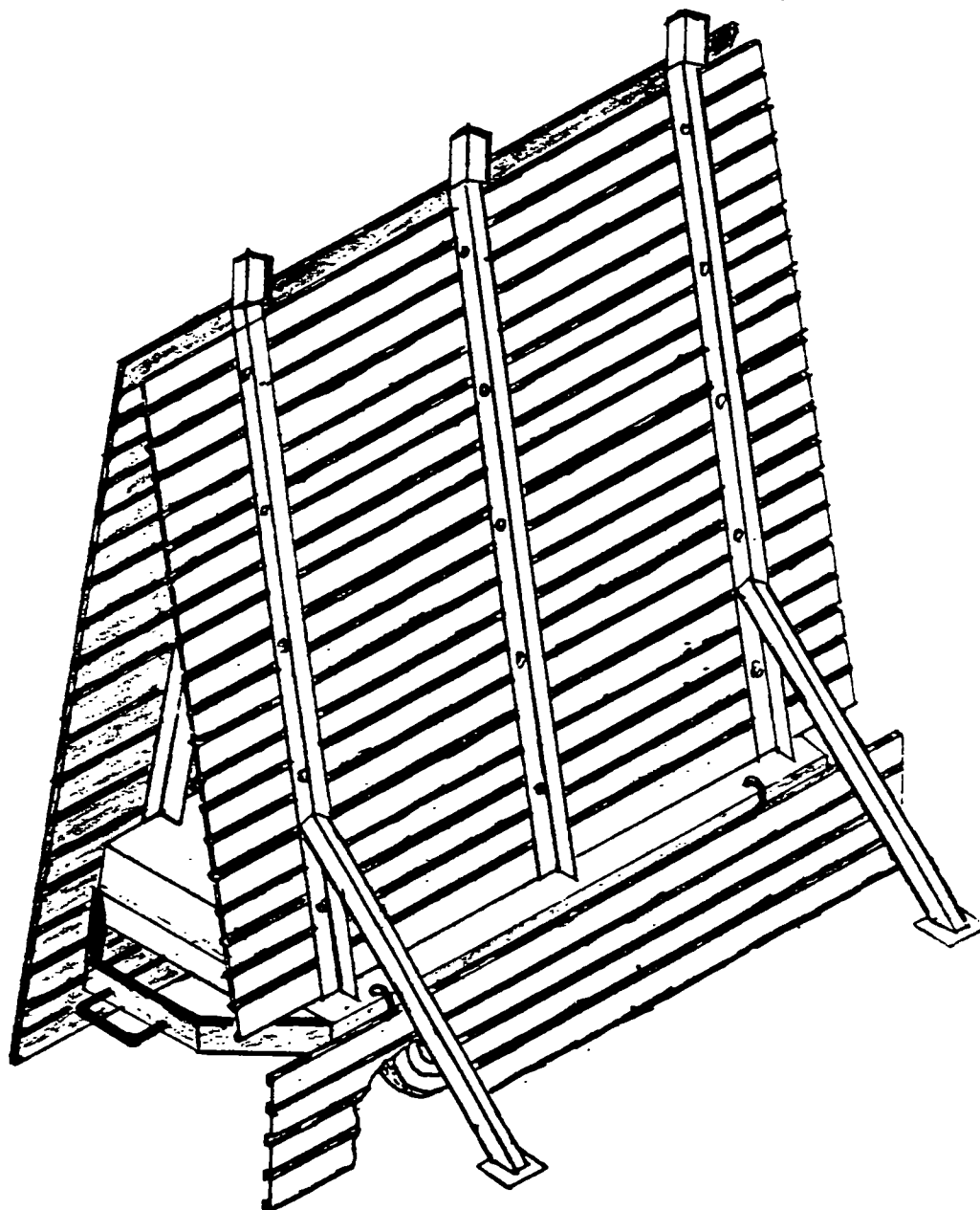


Figure 5-19. Mobile M8A1 revetment.

Table 5-5. Bill of Materials per Dolly for Mobile M8A1 Revetments

Description	FSN	Ordering unit	Quantity
M8A1 matting.....	5680-782-5577	Bundle	1½
7x10x.64 cm (3 in x 4 in x ¼ in) steel angle.....	9520-954-5651	Foot	80
Trailer (dolly).....	3920-856-1342	Each	1
.64 cm (¼ in) steel plate.....	9515-229-0196	Plate	½ ₂₅
1.91 cm (¾ in) bolt 35 cm (14 in) long.....	5306-226-8987	Each	4
1.91 cm (¾ in) bolt 14 cm (5½ in) long.....	5306-964-0974	Each	2
.64 cm (¼ in) bolt 3.8 cm (1½ in) long.....	5306-010-9219	Fifty	¼ ₁₀
.64 cm (¼ in) bolt 3.8 cm (1½ in) long.....	5306-NSN	Gross	⅓
.79 cm (⅝ in) U-bolt.....	5306-426-8469	Each	4
.64 cm (¼ in) chain assy w/hook.....	4010-132-8050	Each	2
1.27 cm (½ in) nut.....	5310-012-5536	Fifty	¼ ₁₀
.64 cm (¼ in) nut.....	5310-010-9084	Hundred	½
1.27 cm (½ in) washer.....	5310-012-0390	Each	5
.64 cm (¼ in) washer.....	5310-NSN	Gross	⅓

CHAPTER 6

CONSTRUCTION PLANNING

6-1. Job Management

a. Objective. The objective of job management is efficient use of available resources (labor, equipment, and materials) to complete the assigned construction tasks. Job management is based upon construction planning, scheduling of job tasks, and competent supervision of all phases of construction. These elements of job management are so interrelated and interdependent that neglect of any one will hurt the other two.

b. Planning Factors. The following planning factors should be considered in all types of construction including revetments.

(1) *Resources.* Labor, equipment, and materials available.

(2) *Job tasks.* Reduction of the total construction effort to subordinate job tasks in terms of available resources.

(3) *Local conditions.* Anticipated conditions which may delay or otherwise affect scheduling such as abnormal weather, night operations, or enemy interference.

(4) *Supplementary requirements.* Associated activities or requirements indirectly related to the construction include temporary drainage, material storage space or facilities, movement and assembly of equipment, and administrative support of labor and equipment forces.

c. Scheduling. Scheduling consists of establishing controls for each work phase to achieve maximum economy in manpower and materials. Each job or task schedule should provide for—

(1) Maximum output of manpower with minimum overhead personnel.

(2) Efficient use and maintenance of equipment.

(3) Timely procurement, delivery, stockage, and issue of materials.

(4) Any coordination required.

d. Supervision. Responsibility for the job tasks of the actual construction must be delegated to the most competent supervisors available. Each supervisor must have the necessary tools and materials or access to them, together with specific guidance about his responsibility

and the time phases in the overall plan of construction. The delegation of tasks should avoid overlap or the division of a single responsibility between task groups.

6-2. Mass Production

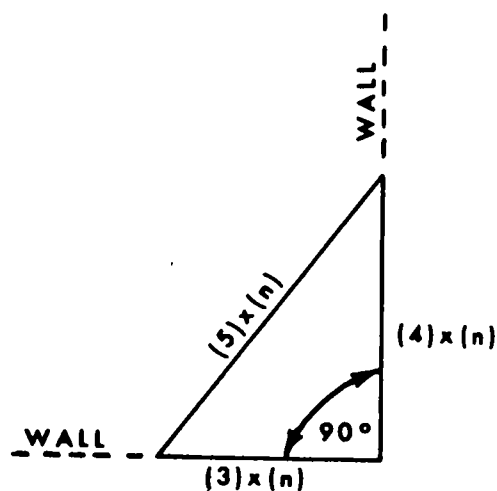
The organization of the construction force should be suited to the type of structure. The job schedule normally should include a breakout of tasks that can be mass produced by assembly line procedures. Revetment components that can be mass produced under qualified supervision are retaining wall sections, for either gravity or bulkhead type revetments, standoffs, and anchorage assemblies. This phase of organization limits the number of supervisors, promotes rapid training of unskilled labor through repeated performance of similar tasks, and reduces the amount of coordination required between job tasks.

6-3. Construction Capability

Specific conditions on each job site will influence the capability of labor and equipment to construct the revetment. The production capabilities of selected equipment items and personnel are contained in TM 5-331A through TM 5-331E, TM 5-333, and FM 5-34. Since no experience factors for this type of construction are available, accurate production records would provide valuable assistance to guide future planning and scheduling of similar construction. Organizations accumulating such data should forward that information in accordance with paragraph 1-2.

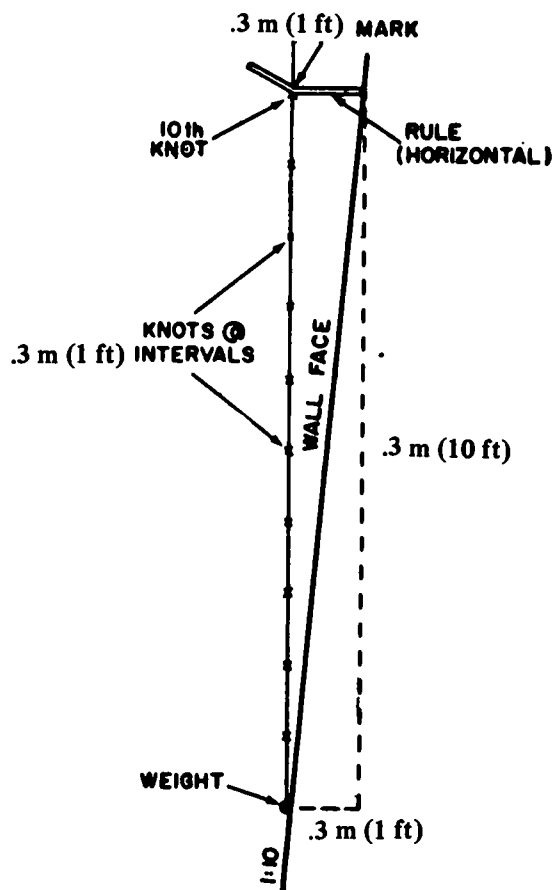
6-4. Job Organization

a. Manpower. Revetment construction usually will employ one or more of several types of labor including troops (engineer and nonengineer) and local inhabitants. The job organization and supervision should take advantage of any known abilities in the potential work force. Since training in the various aspects of the construction tasks influences manpower effectiveness, the construction schedule should provide for necessary on-the-job training.



WHERE n IS ANY NUMBER

① RIGHT ANGLE CHECKING-SQUARING



② SLOPE CHECKING

Figure 6-1. Expedient field checks.

b. Materials. A forecast of material requirements provides timely information for both supply and construction personnel and insures that required materials are available. Prestockpiled materials will prevent work stoppage or delay due to delivery delay or failure.

c. Equipment. Some mechanical equipment will be required to supplement handtools and manual labor. Steps should be taken to insure that lack of maintenance or misuse does not hinder the effective use of mechanical equipment. Scheduled maintenance and inspections are a must to prevent equipment breakdown.

6-5. Layout of Revetments

The actual layout of revetments should be made with a transit if possible. If a transit is not available, the revetment can be laid out using a compass and tape as follows:

- Establish the center point of the revetment.
- Establish the centerline of the revetment with the compass.

c. Measure (to either the right or left of the centerline one-half the width of the structure.

d. Establish a parallel line. This becomes the inside of the base of one side wall.

e. Locate the rear wall by measuring one-half the length of the revetment along the centerline toward the rear.

f. Square the resulting corner using the tape and the 3-4-5 triangle method (fig 6-1).

g. Repeat c through f above to lay out the other wall.

h. Points can be marked with stakes or nails with bright cloth attached. Other methods of marking are acceptable if the construction personnel can readily identify the marker. Twigs or branches should not be used unless a supplemental marking device is attached to avoid mistaken identity.

i. During the construction the actual wall points may be lost several times. However, they can be easily relocated by establishing reference points away from the work area and recording the locations on a sketch of the site.

j. Slopes can be easily checked by using a field expedient consisting of a weighted string and a carpenter's rule. Knots are tied in the string at even .3m (1 ft) intervals. A 1:10 slope would be where the 10th knot in the string intersects

with the .3m (1 ft) mark on the rule when the rule is horizontal and the other end of the rule and the weight on the string just touch the slope (fig 6-1).



CHAPTER 7

CONSTRUCTION PROCEDURE

7-1. Construction of Standoffs

a. Construction Details. The use of a standoff (para 1-110b) is optional but desirable. See figures 7-1 through 7-4 for details.

b. Anchorage. With the use of a standoff it may become necessary to provide special anchorage to preclude blowdown as a result of blast effects of moving aircraft. See figures 7-5 and 7-6 for anchorage details.

c. Drainage. It may be necessary to install a temporary system to drain the area during construction; however, this system should be planned to become a part of the final drainage system.

d. Assembly Details. Mass production can be used to construct standoff walls as follows:

(1) *Dimensioned timber.* Walls can be assembled in sections before erection. The framing, consisting of vertical and horizontal structural members and/or temporary scabbing, is assembled as the first step. After the frame is constructed, the sheathing is attached. The sections can be assembled on site or at some preassembly site.

(2) *Logs.* If logs are used, instead of dimensioned timber, to frame the standoff, the exterior or exposed horizontal members are laid out first. The layer of vertical logs is then attached, and finally the interior horizontal members.

e. Concurrent Operations. If the wall is being constructed as a retaining wall—the waterproofing agent is applied, anchor points on the walls are marked, and necessary adjustments of the anchorages are made.

f. Postholes. Postholes are dug and anchor points are constructed at the same time. Temporary anchorages may be required until construction of the main wall is completed.

g. Erection. After each section is completed, it is transported to the erection site and tilted into position. Each section should be placed so that a gap of about 1.27 cm (½ in) is left between it and the next section to make repairs easier and to reduce combat damage.

h. Anchorages. Anchor cables and supports are then loosely attached and the wall is alined.

Once alined, the cables and supports are tightened and the postholes are backfilled, preferably with concrete.

i. Final Drainage. Temporary drainage structures are inspected, repaired, or improved, and combined with the permanent system when possible.

7-2. Construction of Sandbag Revetments

a. Advantages. Revetments constructed with filled sandbags are a practical expedient for fortifications, particularly when equipment is limited to handtools and when skilled assistance is not available to supervise the construction of other types of protective structures. Damage to the structure can be easily repaired using new bags. The bags can be filled at the construction site with sand hauled to the location, which is preferable, or they can be filled where the sand is available and hauled to the site. This latter procedure may result in damage to the bags during handling.

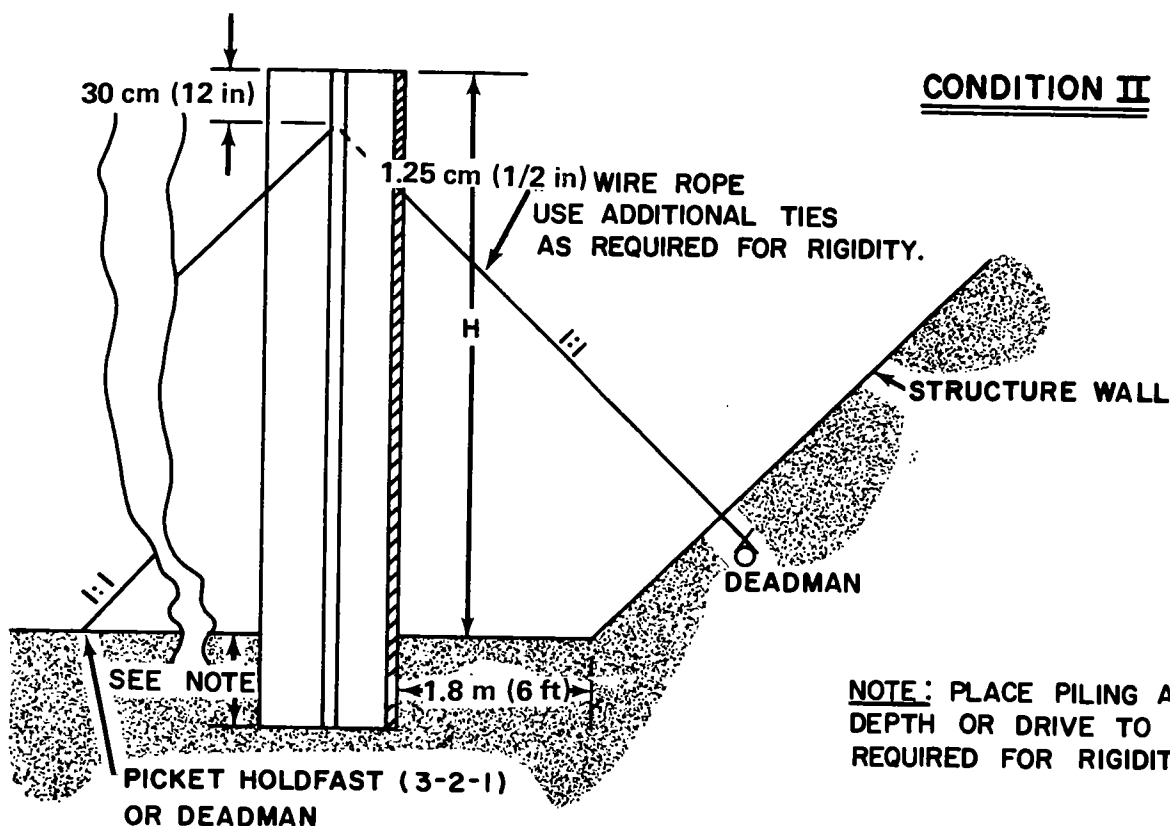
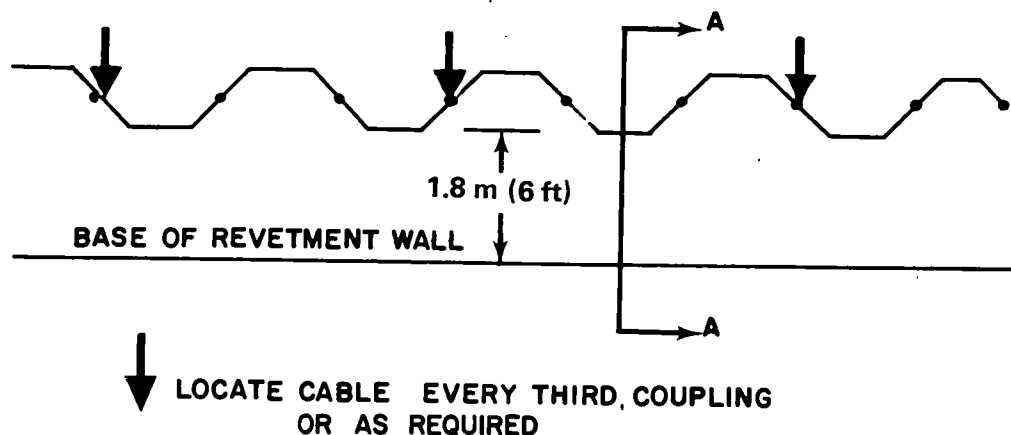
b. Disadvantages. Sandbags deteriorate rapidly, particularly in damp climates, permitting the filler material to run out. This reduces the protective characteristics and endangers the stability of the revetment. Shell hits have a similar effect, requiring replacement of bags.

c. Construction.

(1) *Material.* Effective sandbag revetments require loose soil. A procedure for stacking bags is explained and illustrated in FM 5-15. Sandbags may be stacked without a retaining wall if the sides of the stacks are sloped approximately 1:5. The deterioration of the burlap bags can be partially overcome by the substitution of a soil cement mixture (para 4-1c) instead of sand.

(2) *Standoff.* A standoff provides substantially more protection when using sandbag revetments. Construction details are discussed in paragraph 7-1 and illustrated in figures 7-1 through 7-4.

(3) *Drainage.* Drainage provided to channel water away from the fortification area reduces settlement and subsequent weakening of the revetment.



SECTION A-A

Figure 7-1. Standoff construction, steel sheet pile—condition II.

7-3. Main Structure—Gravity Revetment

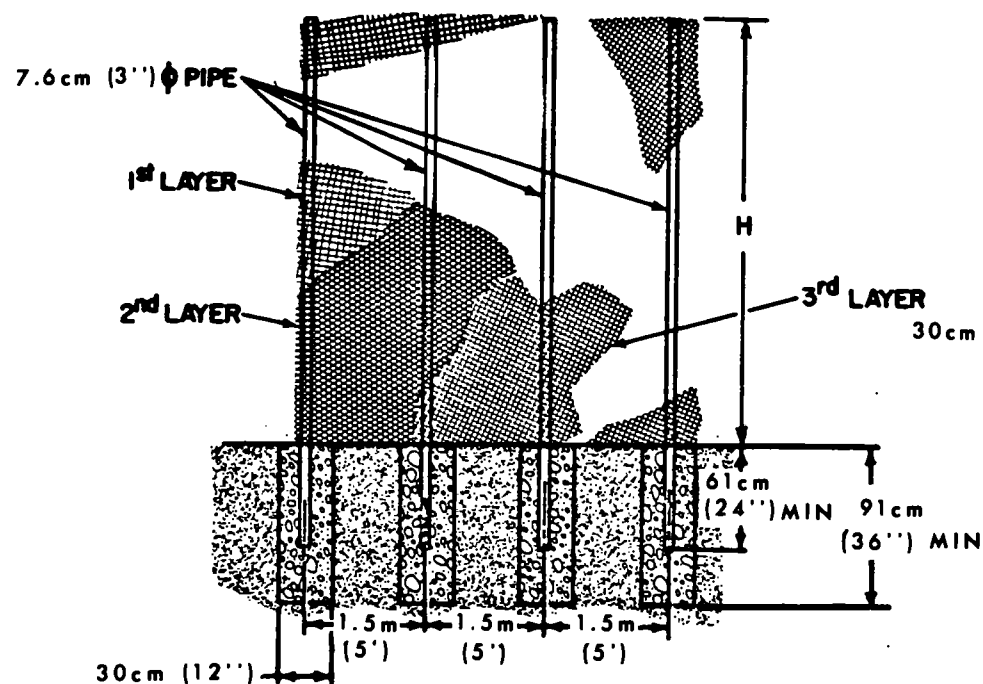
a. *Construction Details.* See figures 5-5 through 5-7 and 7-7 through 7-12.

b. *Drainage.* Follow the procedure outlined in paragraph 7-1c.

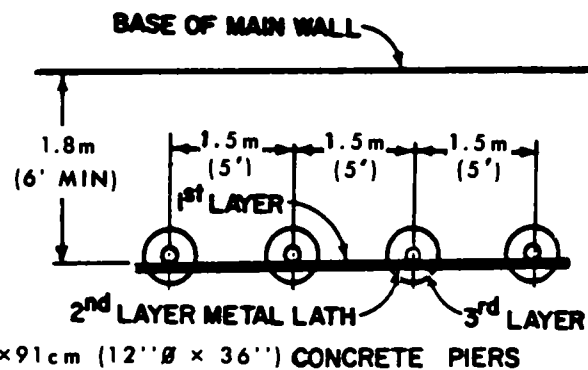
c. *Retaining Wall.* Follow the procedure outlined in 7-1d, e and f to construct retaining wall sections.

d. *Erection.* After the wall sections are completed and waterproofed, place them upright, aline them, and secure them with temporary anchorages. Backfill the postholes, preferably with concrete.

e. *Earth Fill.* Place backfill against the wall but do not disturb the alinement. At the specified heights, construct anchorages and



SIDE VIEW

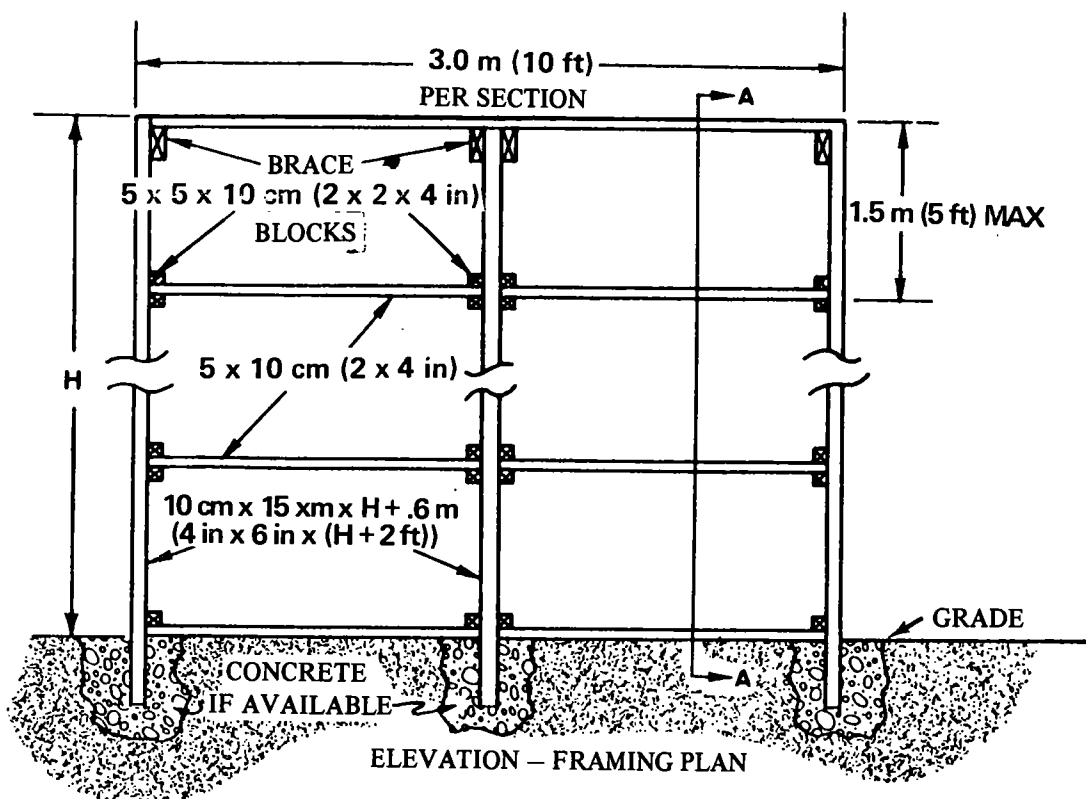


PLAN

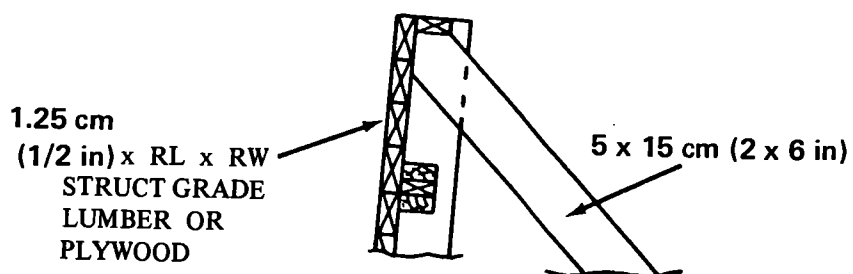
CONNECT MESH TO PIPE
WITH #8 TIE WIRE.
INCREASE PIER DEPTH FOR
HEIGHTS IN EXCESS OF
2.4 m (8')

CONDITION II

Figure 7-2. Standoff construction, expanded metal lath—condition II.



CONDITION III



**NOTES: MAKE EACH SECTION
INDEPENDENT OF
ADJACENT SECTION
LOG POST 10 cm (4 in)
Ø OR WIRE ROPE
1.25 cm (1/2 in) Ø
MAY BE SUBSTITUTED
FOR 5 x 15 cm (2 x 6 in)
BRACE**

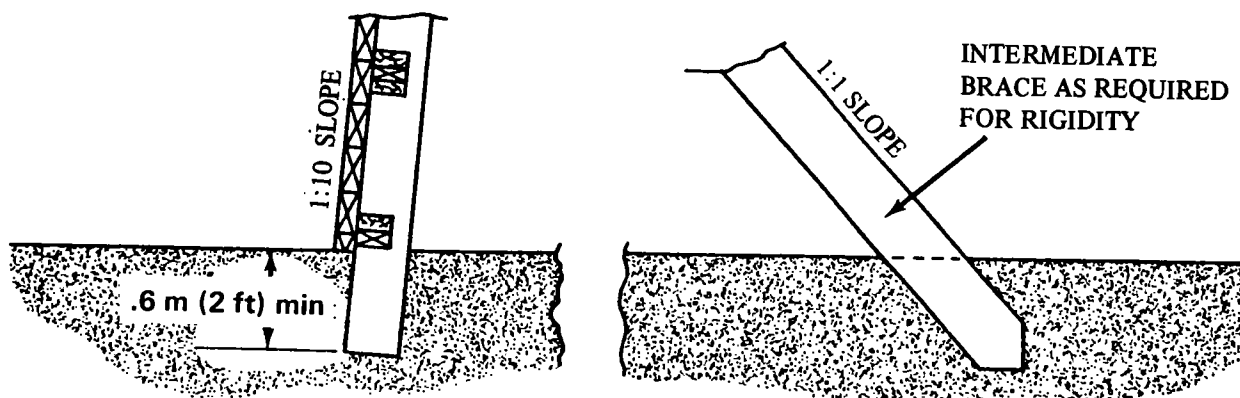
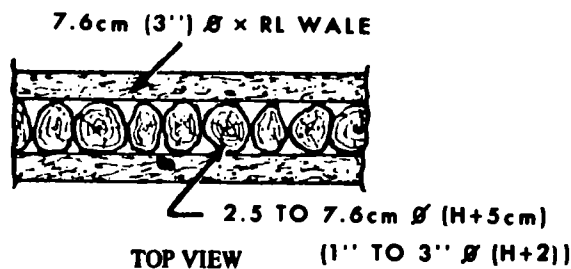
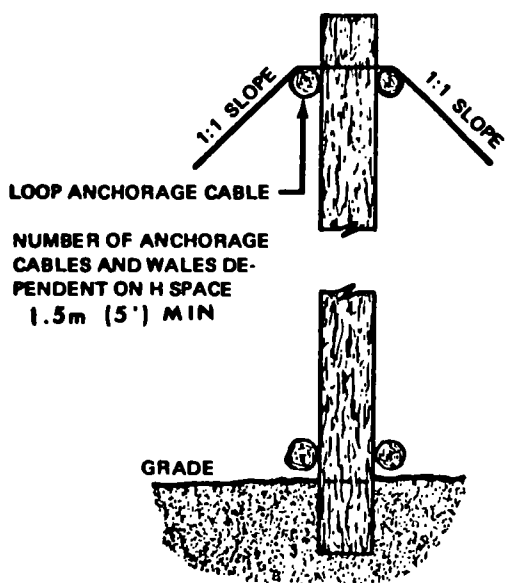
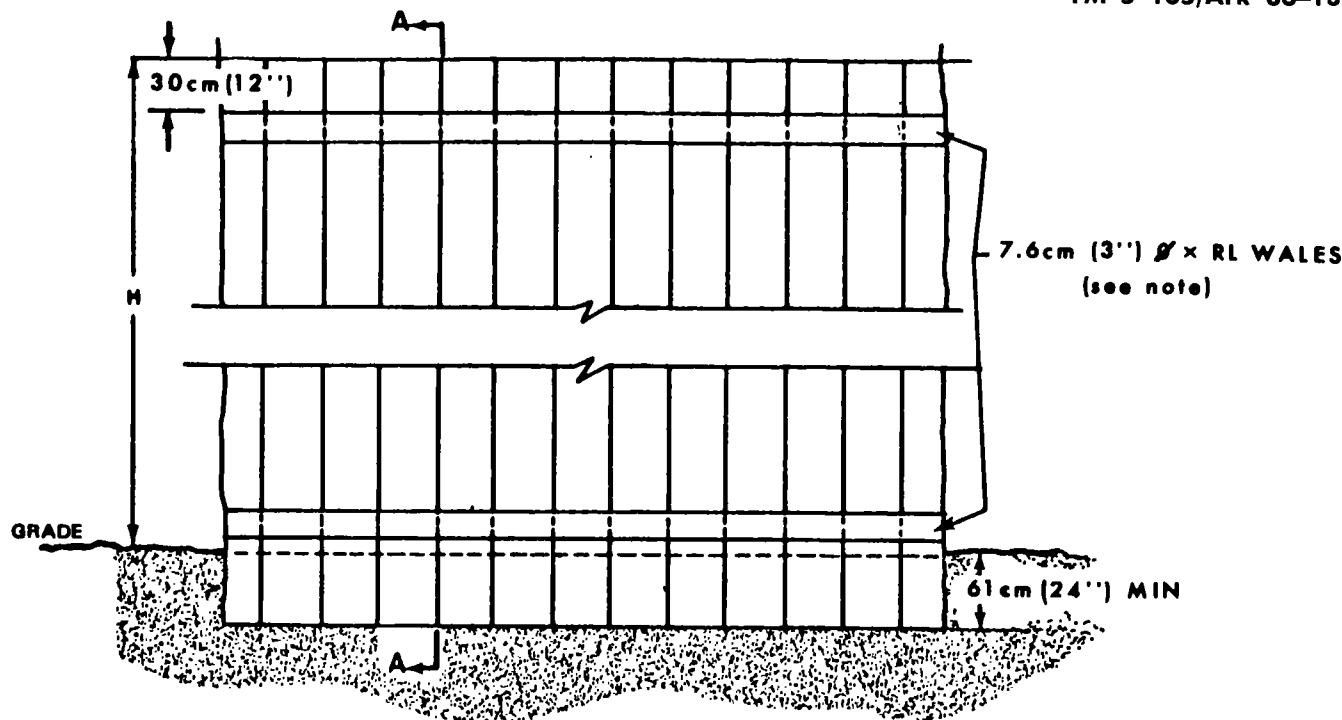


Figure 7-8. Standoff construction, dimensioned timber—condition III.



NOTE:
FOR HEIGHTS OVER 3m (10FT)
USE ADDITIONAL CABLES
AND WALES AS NECESSARY.
USUAL SPACING IS 1.5m (5')

SECTION A-A

Figure 7-4. Standoff construction, logs—condition III.

place anchor cables and deadmen in the earth fill. Tighten the anchorage cable just enough to prevent movement after the work is completed. Remove temporary anchorage if this has not already been done.

f. Protective Cover. After the fill has been placed to the specified height and thickness, place the protective waterproof cover or sod.

g. Final Drainage. Follow the procedure outlined in paragraph 7-1i.

7-4. Main Structure—Earth Revetment

a. Construction Details. See figures 7-7 through 7-12.

b. Drainage. Follow procedures in paragraph 7-1c.

c. Protective Cover. Apply waterproofing or sod.

d. Final Drainage. Follow procedures outlined in paragraph 7-1i.

7-5. Main Structure—Bulkhead Revetment

a. Construction Details. See figures 5-5 through 5-7, 7-5, 7-6, and 7-13 through 7-18.

b. Drainage. Follow the procedure outlined in 7-1c.

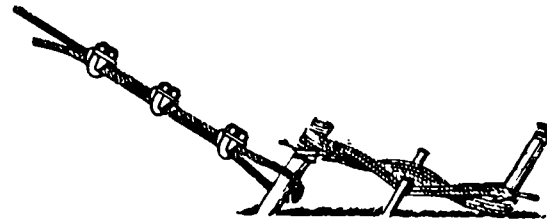
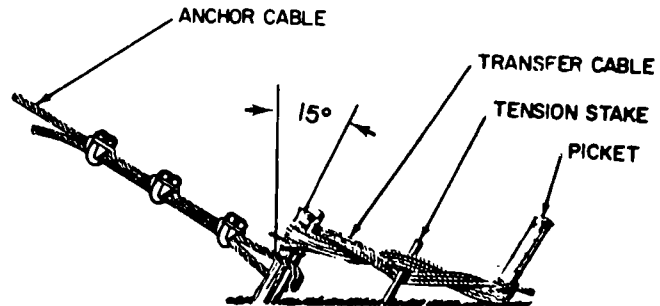
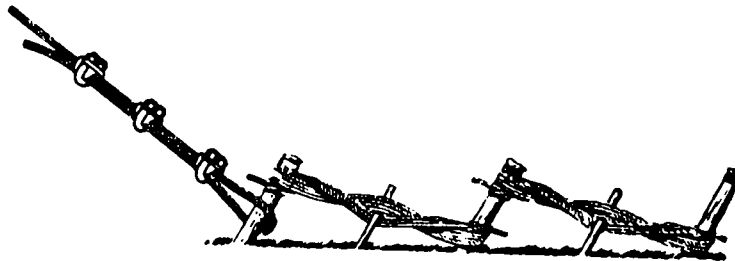
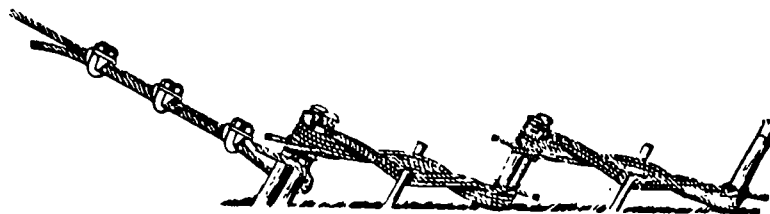
c. Assembly of Wall Sections. Follow proce-

WALL
HEIGHT
(H)

COMBINATION

ANCHOR OR TIE CABLE
(WIREROPE)
SIZE

10	1-1	.64 cm (1/4 in)
12	1-1	.64 cm (1/4 in)
14	2-1 or 1-1-1	.64 cm (1/4 in)
16	2-1 or 1-1-1	.79 cm (5/16 in)
18	3-2-1	.79 cm (5/16 in)
20	3-2-1	.79 cm (5/16 in)
22	3-2-1	.95 cm (3/8 in)
24	3-2-1	.95 cm (3/8 in)
26	3-2-1	.95 cm (3/8 in)
28	3-2-1	1.11 cm (7/16 in)
30	3-2-1	1.11 cm (7/16 in)

**1-1 COMBINATION****2-1 COMBINATION****1-1-1 COMBINATION****3-2-1 COMBINATION***Figure 7-5 Anchorage detail—picket holdfasts and wire rope sizes.*

dures outlined in 7-1d, e and f to construct the inner and outer wall sections.

d. *Erection of Wall Sections.* After both inner and outer wall sections are completed and waterproofing applied, place opposing sections upright. Sturdy spacer blocks are used to hold the walls apart at the specified distances while the tie cables are tightened. Backfill the post-holes, preferably with concrete.

e. *Earth Fill.* Deposit the filler material carefully to avoid displacing the spacer blocks or damaging the tie cables. Tamp the filler as it is deposited for best results and maximum protection.

f. *Protective Cover.* Apply waterproof cover and remove any temporary anchor cables.

g. *Final Drainage.* Follow the procedure outlined in paragraph 7-1i.

7-6. Main Structure—Free Standing Wall

a. Construction Details. See figures 7-19 and 7-20.

b. Drainage. Follow procedure outlined in 7-1c.

c. Forms and Placement of Concrete. Construct forms, and place reinforcing steel and concrete in accordance with procedure contained in TM 5-742.

d. Removal of Forms. See TM 5-742 for details.

e. Final Drainage. Follow outline in paragraph 7-1i.

7-7. Construction Control Checklist

A checklist covering the various construction operations is shown below. Frequent reference to it will assure the supervisor that no important items are overlooked. The list applies to a typical fortification project. It will vary in some details from the specification requirements and construction procedures on any specific project but will serve as a guide.

a. Preconstruction.

(1) Manpower and equipment scheduled for maximum use.

(2) Materials at site and distributed.

(3) Structure dimensions determined:

(a) Interior width.

(b) Interior height.

(c) Width of top of wall.

(d) Width of base of wall.

(e) Location and size of openings.

b. Layout (fig 5-5 through 5-7).

(1) Centerline established.

(2) Corners located.

(3) Reference points (construction references) established.

(4) Inside wall base established.

(5) Outside wall base established.

(6) Standoff established.

(7) Openings located.

c. Standoff (fig. 7-1 through 7-6).

(1) Temporary drainage installed.

(2) Assembly line established—construct wall on ground.

(3) Postholes dug.

(4) Anchor points installed—temporary points may be necessary.

(5) Wall tilted into position.

(6) Gaps left between sections.

(7) Anchorages and supports tightened.

(8) Wall alined.

(9) Anchorages and supports tightened.

(10) Postholes backfilled.

(11) Temporary drainage structures repaired.

d. Main Structure—Gravity Revetment (fig 7-5 through 7-12).

(1) Temporary drainage installed.

(2) Assembly line established—construct on the ground.

(3) Postholes dug.

(4) Waterproofing applied.

(5) Wall tilted into position.

(6) Temporary anchorage attached.

(7) Wall alined.

(8) Temporary anchorage installed.

(9) Postholes backfilled.

(10) Backfill and permanent anchorages installed at the same time.

(11) Wall alinement checked.

(12) Temporary anchorage removed.

(13) Cover placed.

(14) Drainage structure checked and repaired.

(15) Permanent standoff anchorages installed.

e. Main Structure—Earth Revetment (fig 7-12).

(1) Temporary drainage installed.

(2) Soil placed, compacted, and shaped.

(3) Waterproofing or sod applied to revetment.

(4) Drainage structure checked and repaired.

f. Main Structure—Bulkhead Revetment (fig 7-13 through 7-18).

(1) Temporary drainage installed.

(2) Base line for both inner and outer walls established, retaining walls laid in place.

(3) Postholes dug.

(4) Waterproofing applied.

(5) Walls tilted into position.

(6) Walls alined.

(7) Spacer blocks correct length.

(8) Spacer blocks installed.

(9) Tie cable tightened.

(10) Postholes backfilled.

(11) Filler material deposited.

(12) Cover placed.

(13) Drainage structure checked and repaired.

(14) Permanent standoff anchorages installed.

g. Main Structure—Free-Standing Wall (fig 7-19 and 7-20).

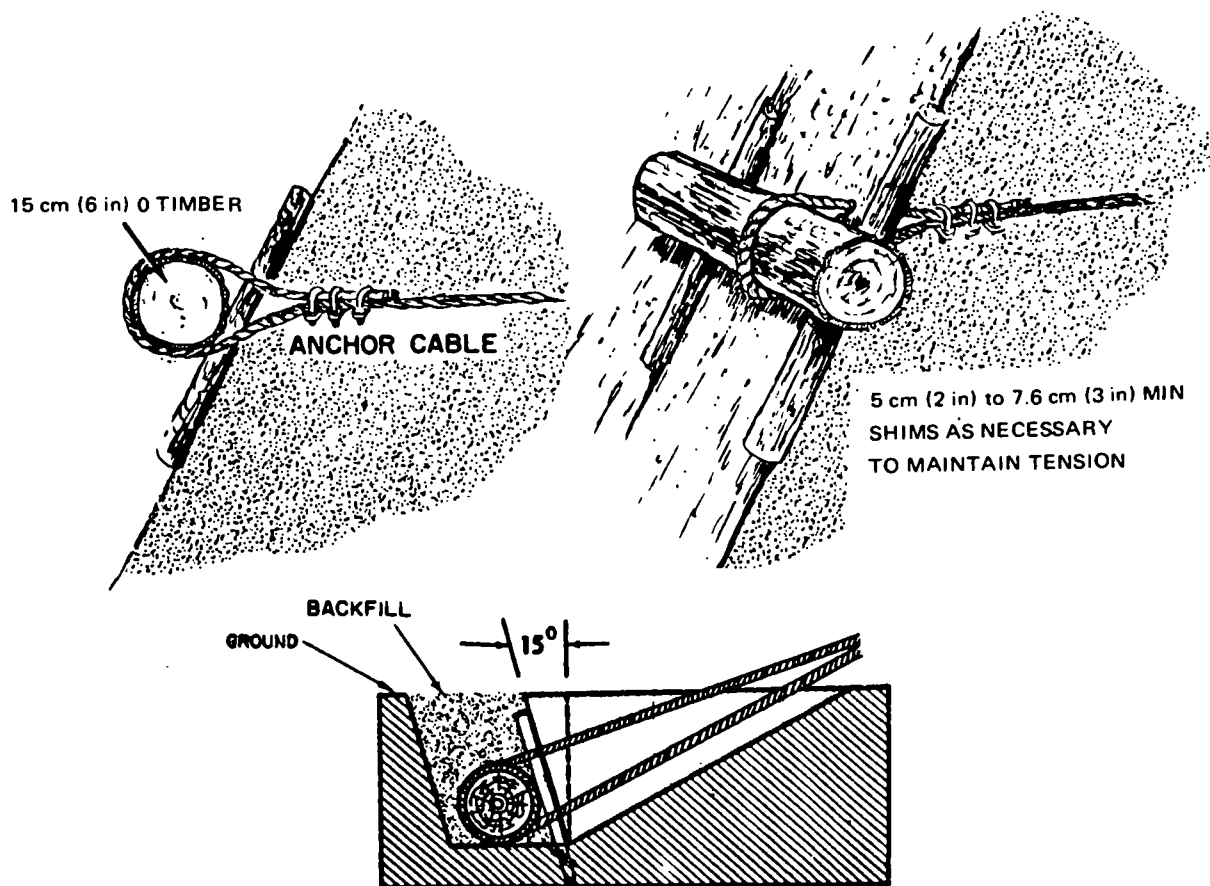
(1) Temporary drainage installed.

(2) Assembly line for forming established.

(3) Material at mixer.

(4) Forms erected and oiled.

ALTERNATE LOG DEADMAN (GRAVITY REVETMENTS)



LOG DEADMAN

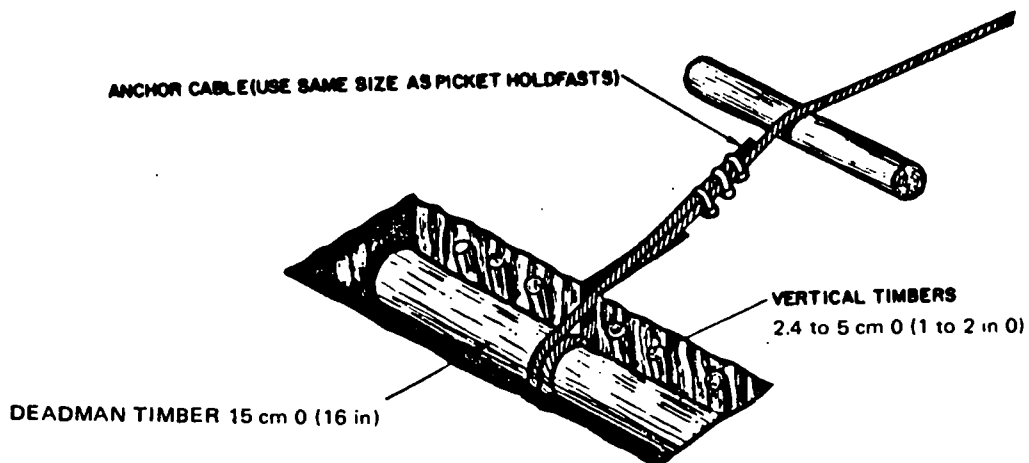


Figure 7-6. Anchorage detail—log deadmen.

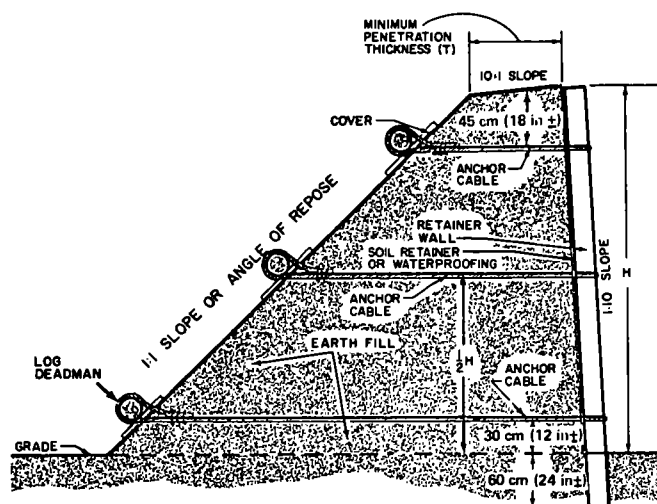


Figure 7-7. General details of gravity revetment.

- (5) Material mixed and placed.
- (6) Forms stripped after use.
- (7) Curing material applied.
- (8) Footing backfilled.
- (9) Drainage structure checked and repaired.
- (10) Preservative applied after curing.

7-8. Employment of Timber Posts for Support of a Thin-Walled Retention 3.66m (12 ft) in Height

a. Fifteen by thirty cm (6x12 in) timber posts should be placed 1.2-1.5m (4 to 5 ft) in the ground depending upon the condition of the soil. If soil properties are poor or unknown the maximum post depth is required. It is also recommended that the horizontal bearing area be increased by attaching 5x30cm (2x12 in) lumber (or larger) to both 15cm (6 in) dimensions of each post. These attachments should extend from the ground surface to the bottom of the post.

b. In concrete, 15x30cm (6x12 in) posts should be set .9-1.2m (3 to 4 ft) deep. The maximum depth is required if soil conditions are poor or unknown.

c. Fifteen by thirty cm (6x12 in) timber posts buried in soil or concrete may fail due to structural or foundation failure. A structural failure involves a bending failure of the post whereas a foundation failure involves an upheaval of the concrete mass or soil material surrounding the post. A structural failure is the more desirable as it indicates that the post system has reached its maximum load carrying capacity. Figure 7-21 presents a comparison of posts buried in soil or concrete. The figure shows that foundation failures occurred for cases I, II, IV, and V while the posts failed structurally for cases III and VI.

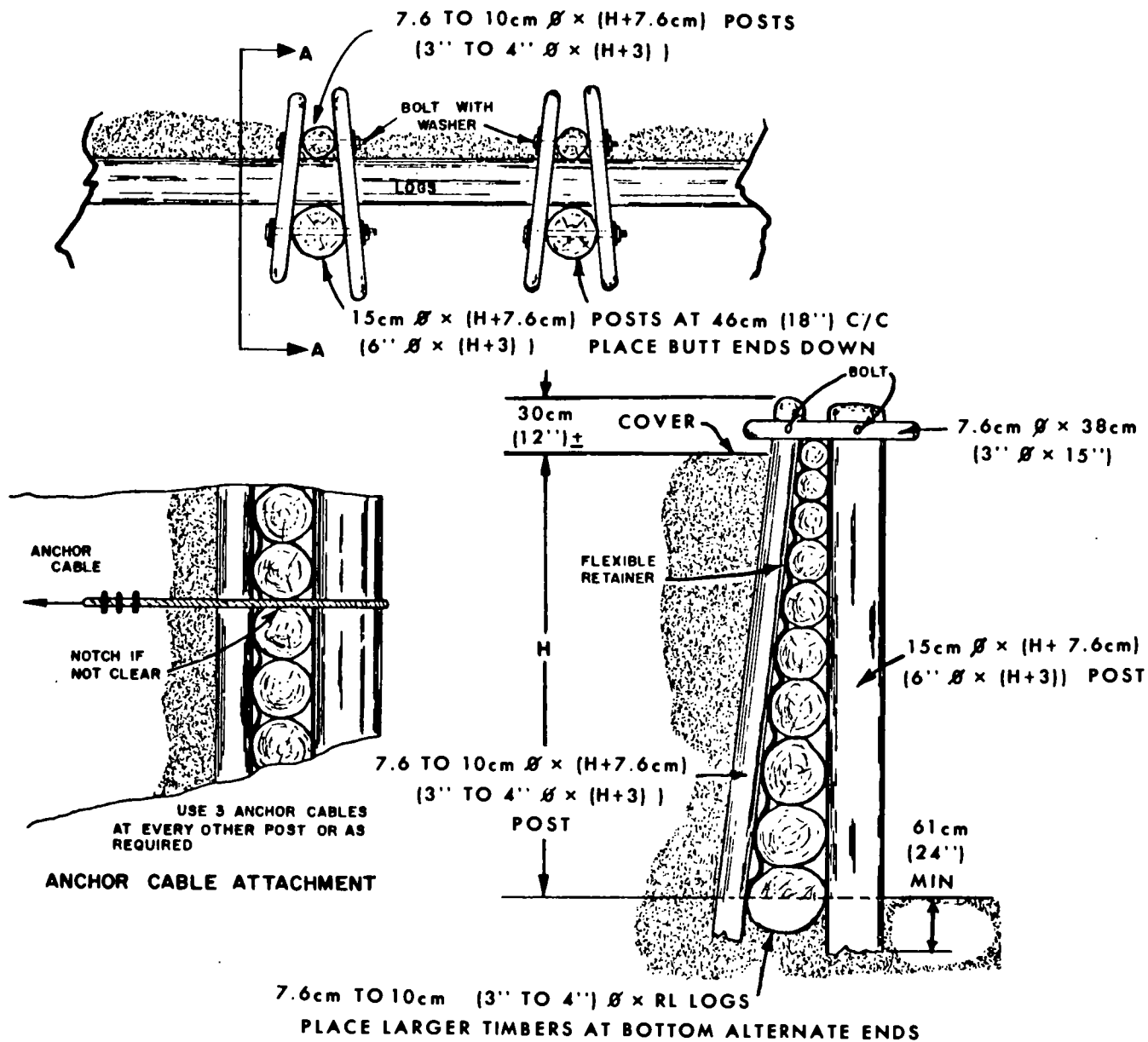


Figure 7-8. Log constructed gravity revetment.

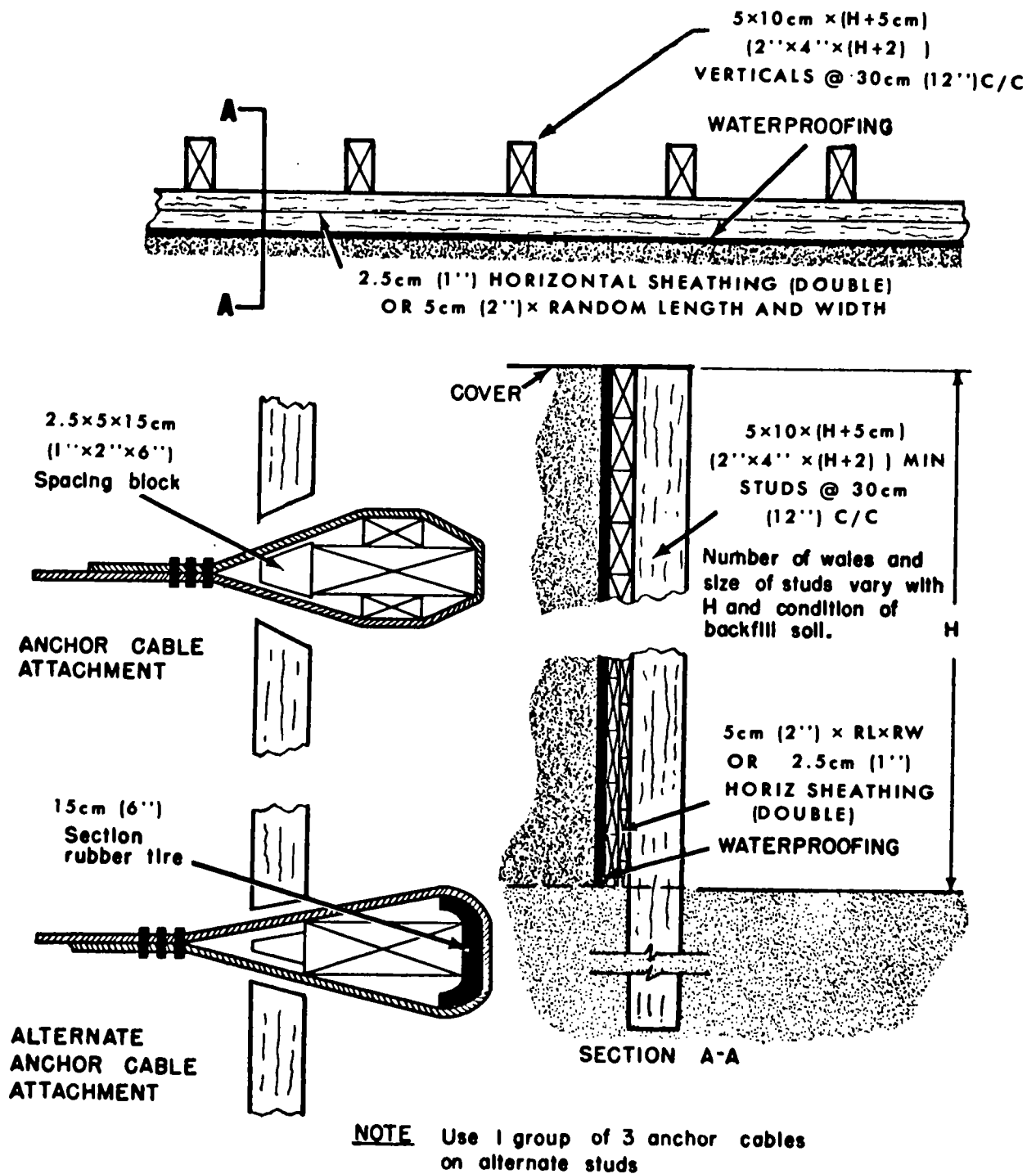


Figure 7-9. Dimensioned timber constructed gravity revetment.

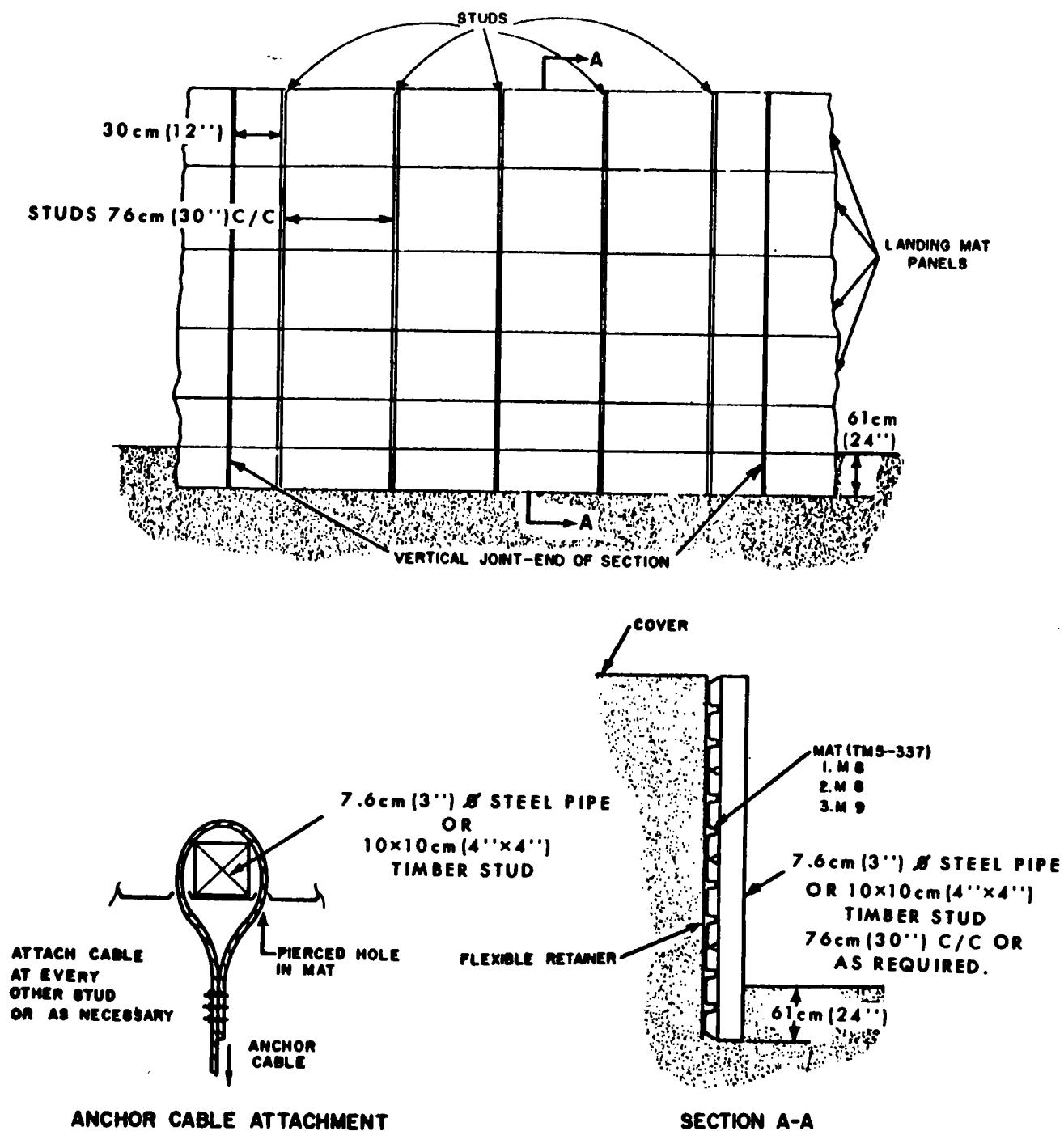
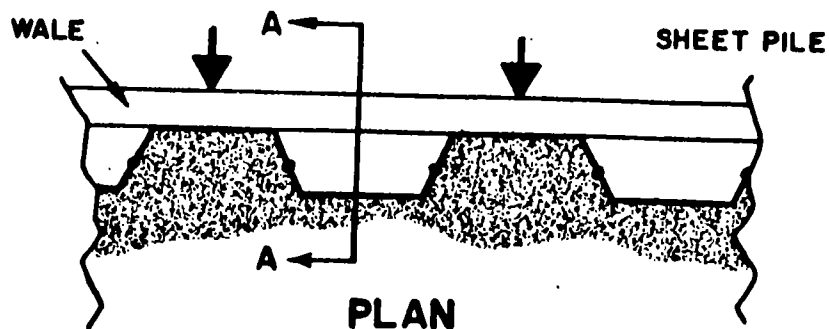


Figure 7-10. Landing mat constructed gravity revetment.

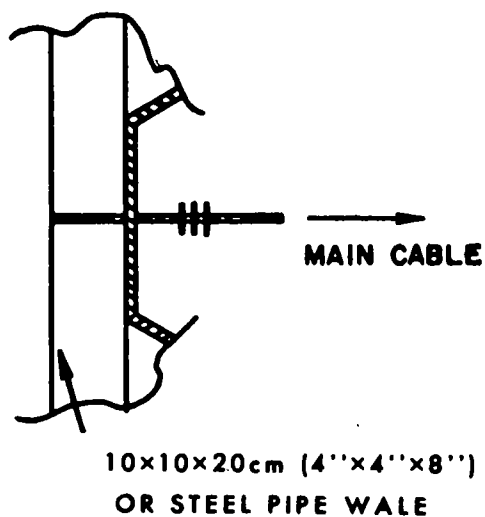


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POINTS FOR MAIN
CABLE ATTACHMENT
SPACE AS REQUIRED

TYPES OF SHEET PILE
IN ORDER OF PREFERENCE

1. ARCHWEB
2. STRAIGHT WEB
3. Z-TYPE



MAIN CABLE ATTACHMENT

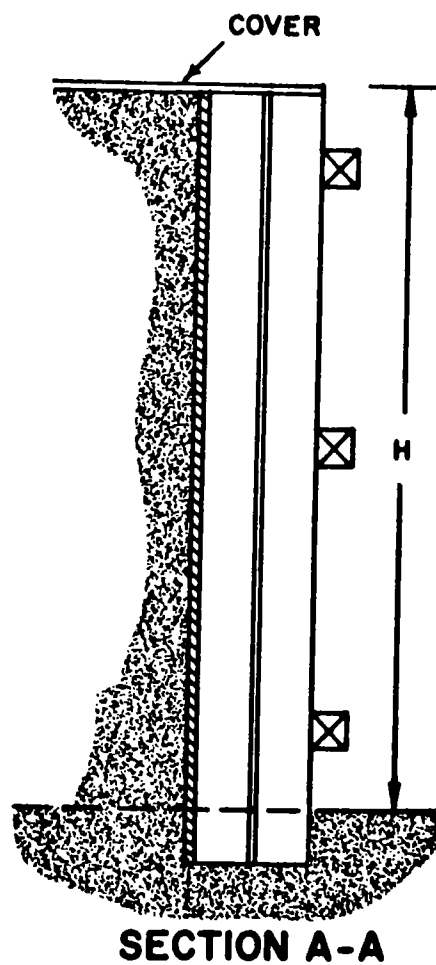
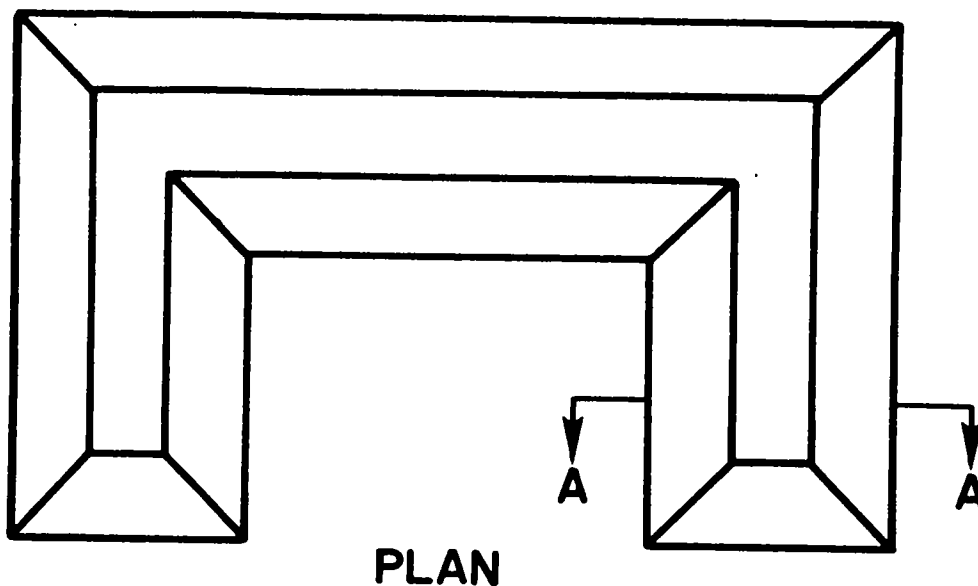
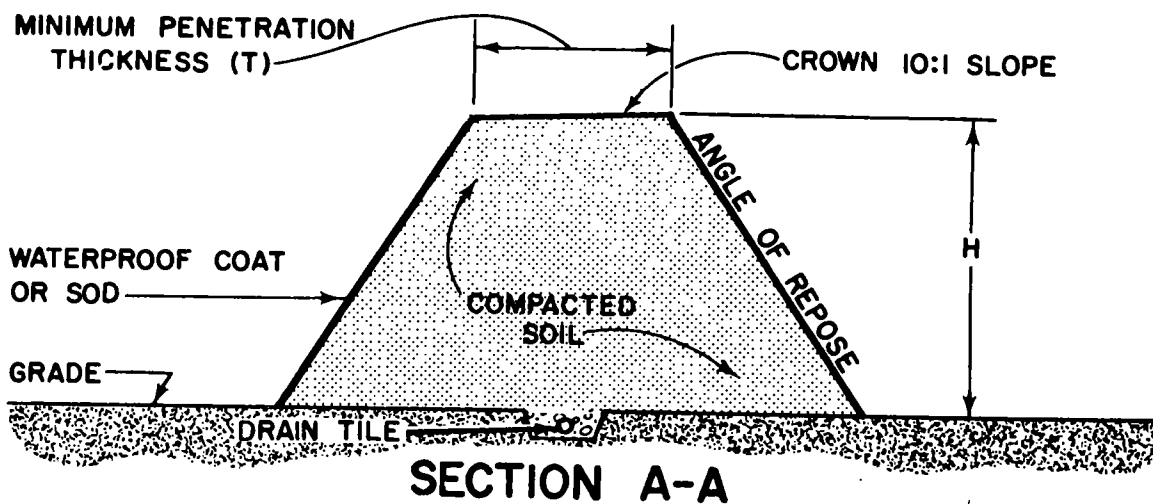


Figure 7-11. Steel sheet pile constructed gravity revetment.



PLAN

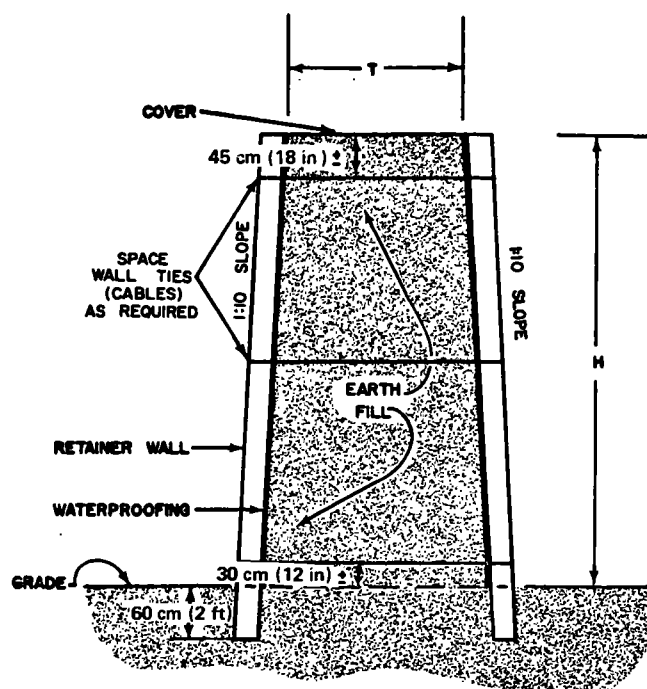


SECTION A-A

NOTE :

WATERPROOFING MAY BE ASPHALT CUTBACK OR CEMENT SLURRY. TRAFFIC ON THE REVETMENT MUST BE PROHIBITED IN ORDER TO PRESERVE THE COATING.

Figure 7-12. Earth constructed gravity revetment.



NOTE:
WALL TIES SAME SIZE AS
ANCHOR CABLES

Figure 7-18. General details, bulkhead revetment.

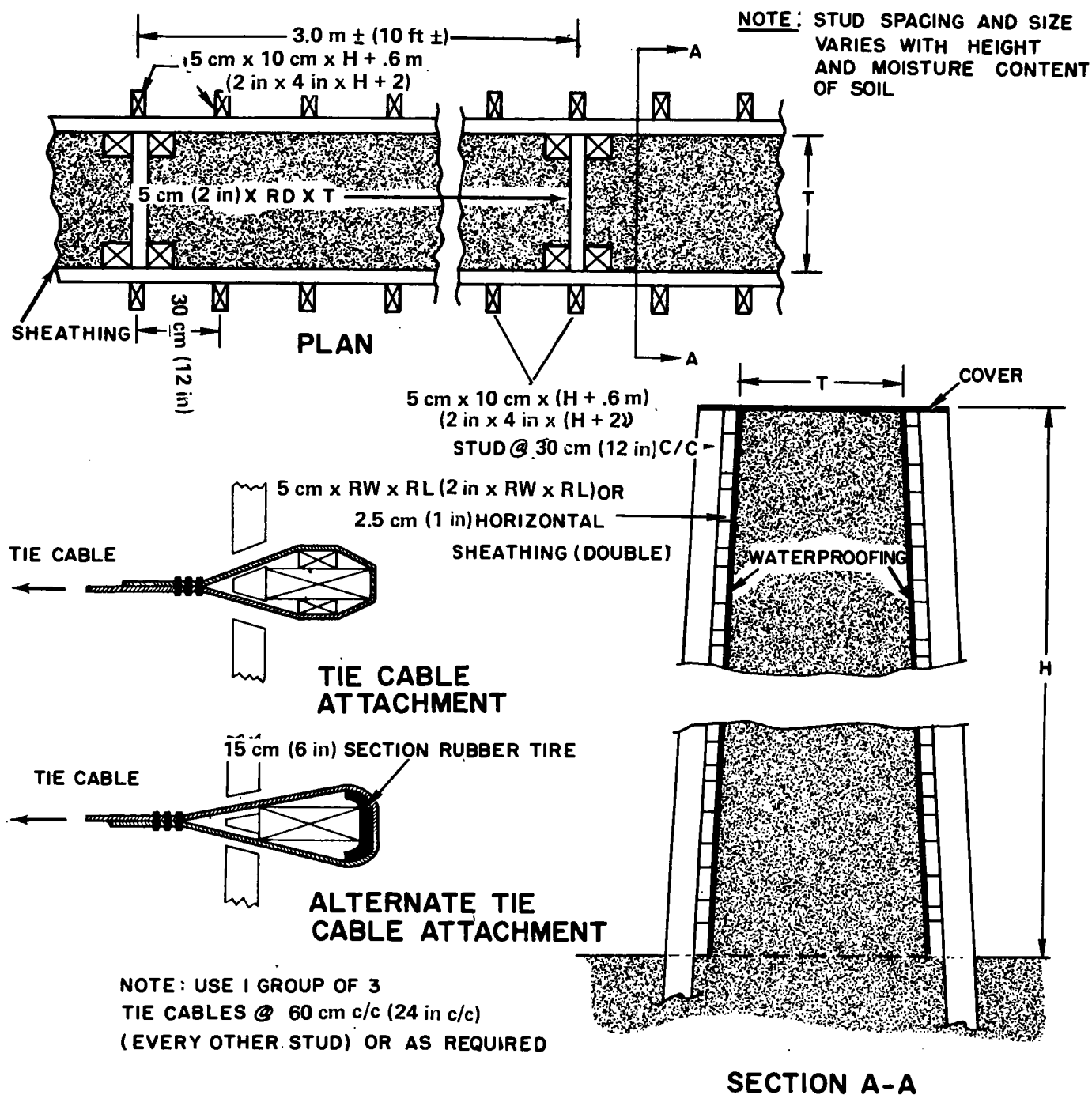
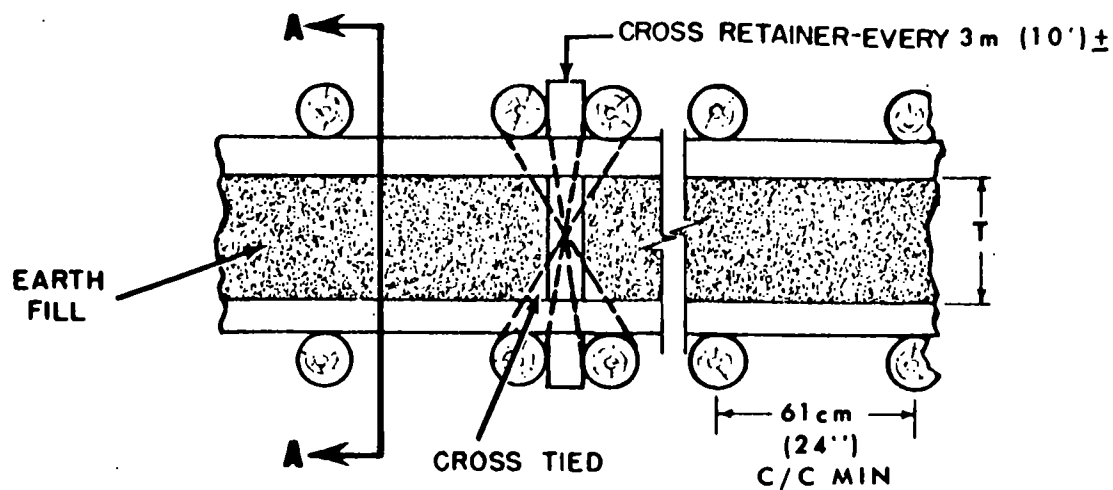
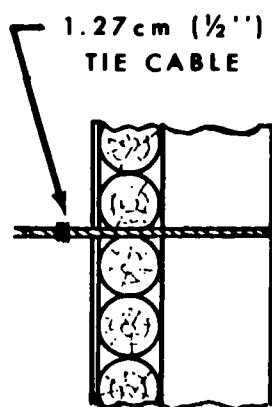
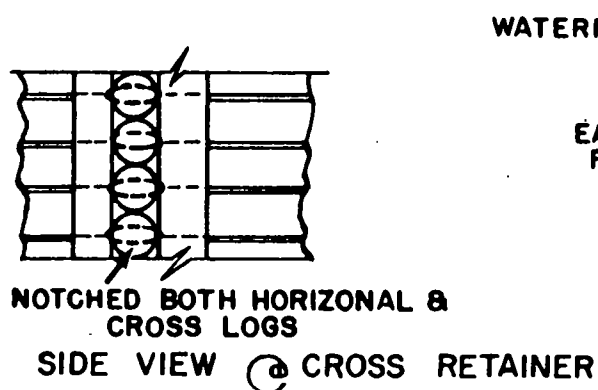


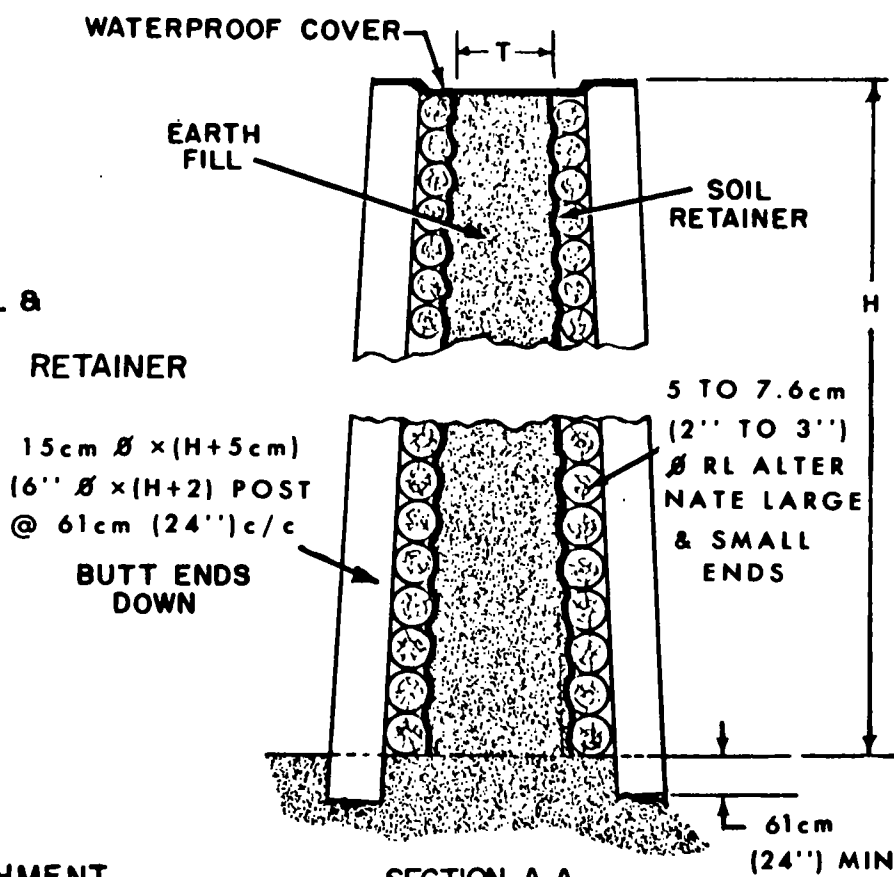
Figure 7-14. Dimensioned timber constructed bulkhead revetment.



PLAN VIEW
SIZE & SPACING OF POSTS
VARIES WITH HEIGHT



ANCHOR CABLE ATTACHMENT



SECTION A-A

Figure 7-15. Log constructed bulkhead revetment.

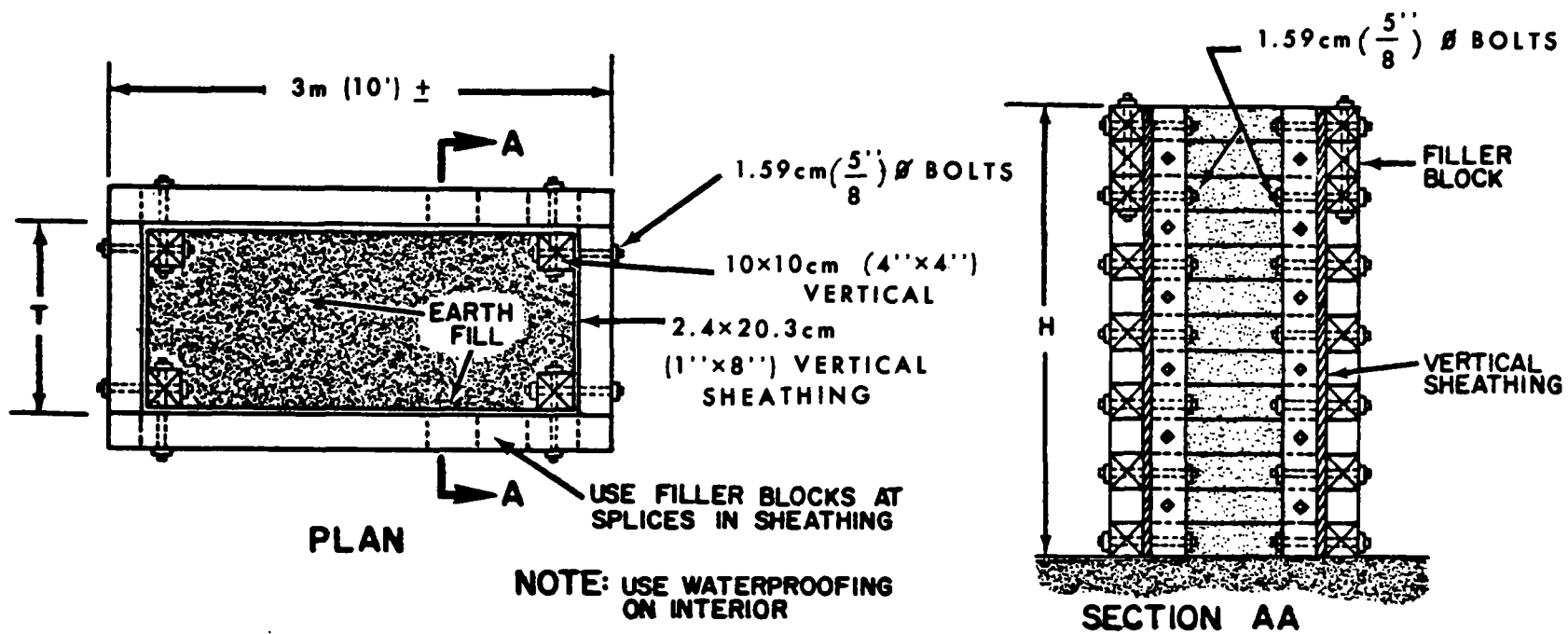


Figure 7-16. Prefabricated dimensioned timber crib constructed bulkhead revetment.

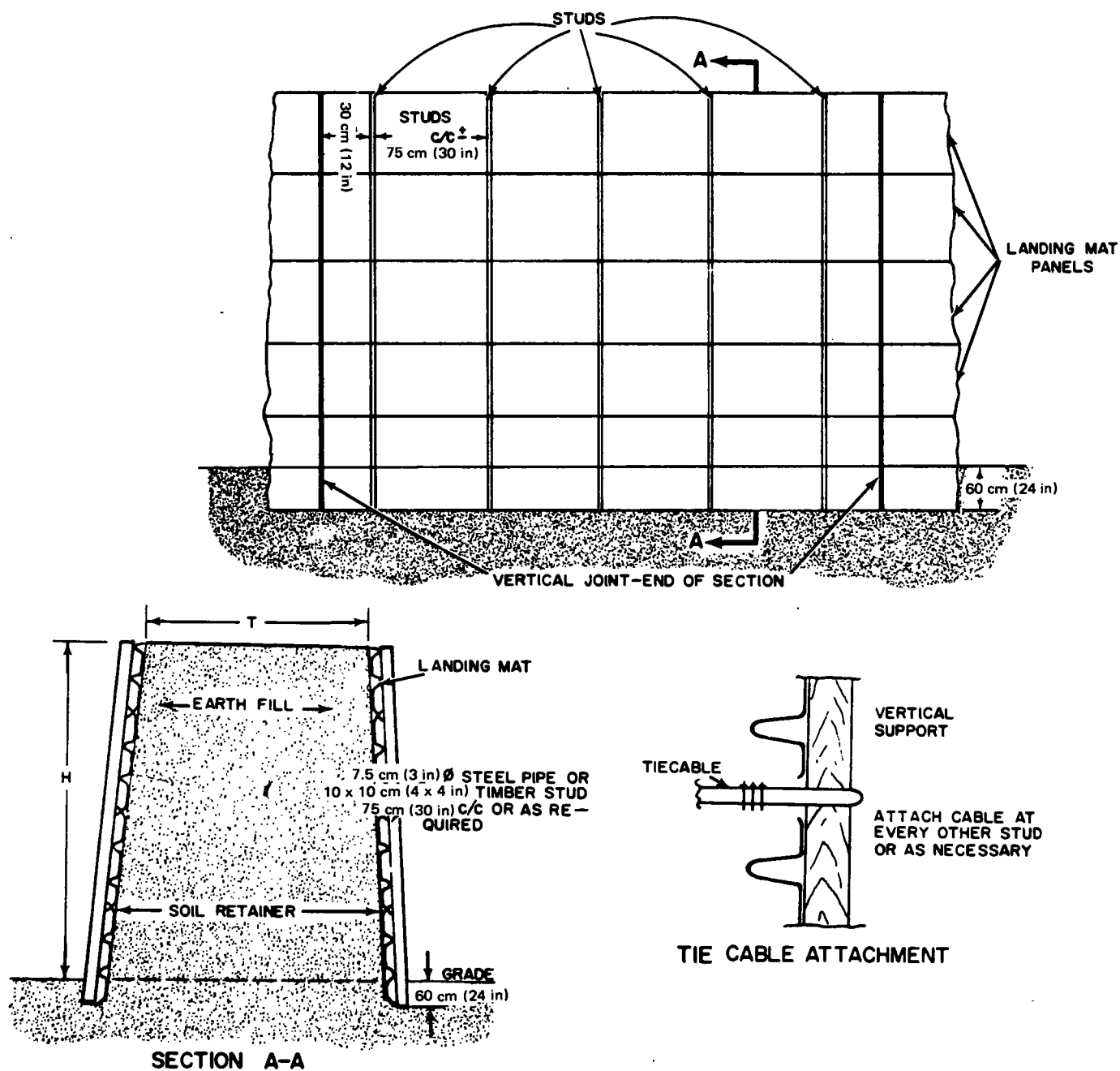
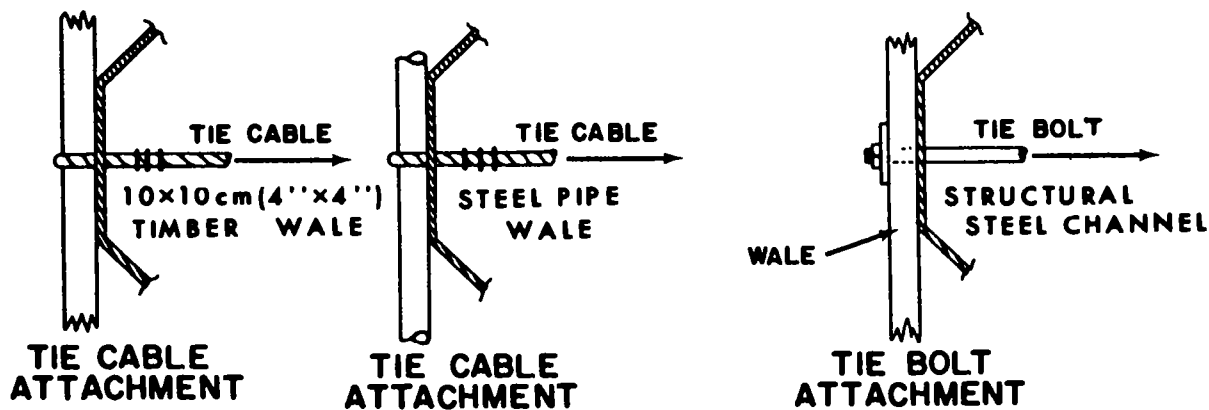
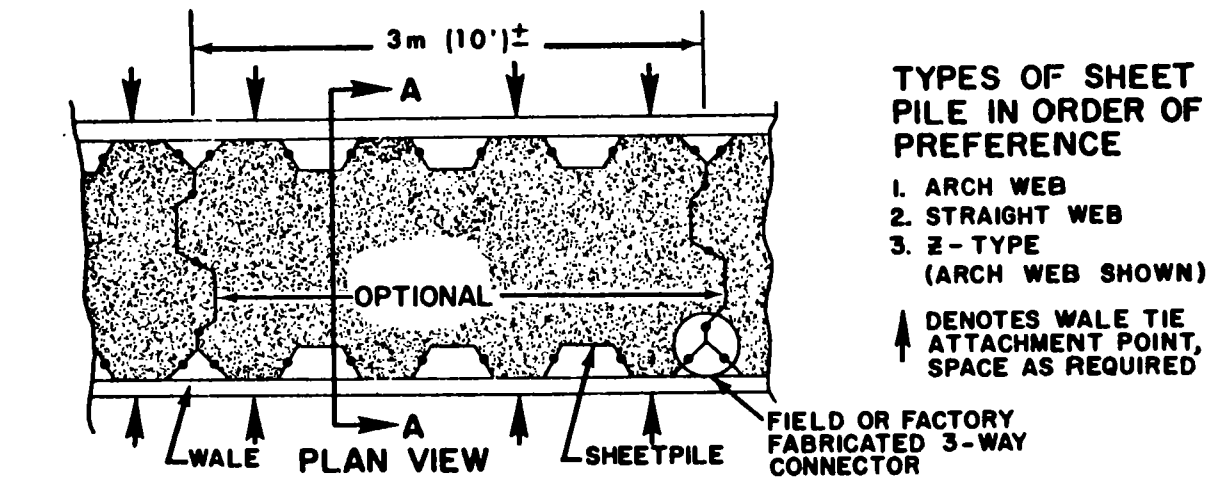


Figure 7-17. Landing mat constructed bulkhead revetment.



DRIVE PILES VERTICALLY

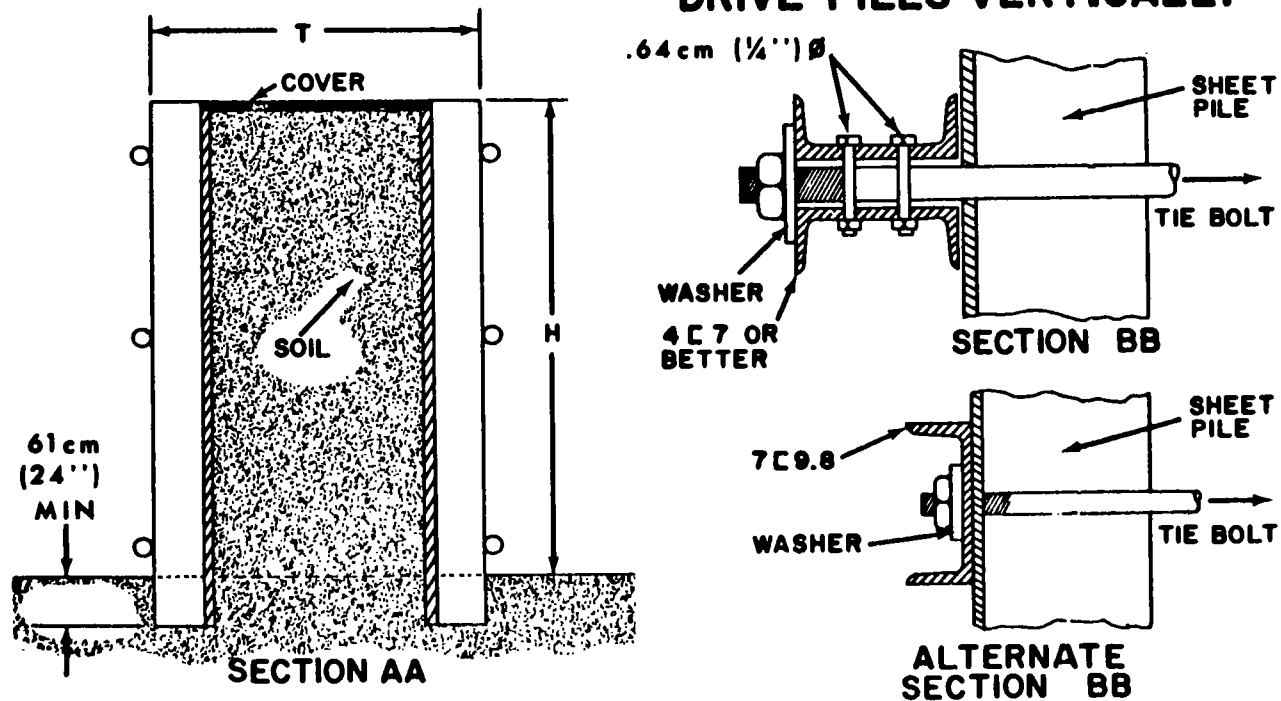


Figure 7-18. Steel sheet pile constructed bulkhead revetment.

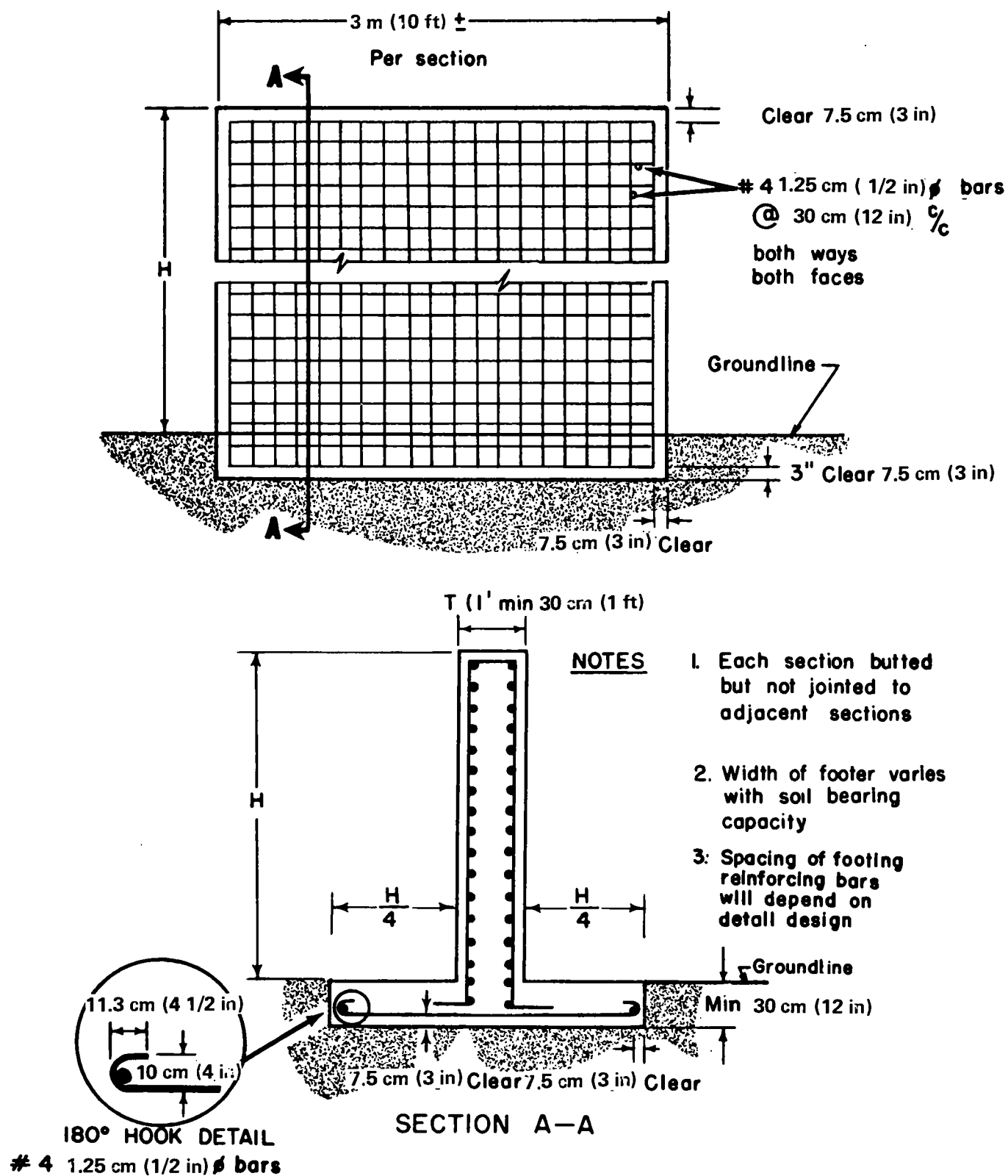


Figure 7-19. Reinforced concrete free-standing wall.

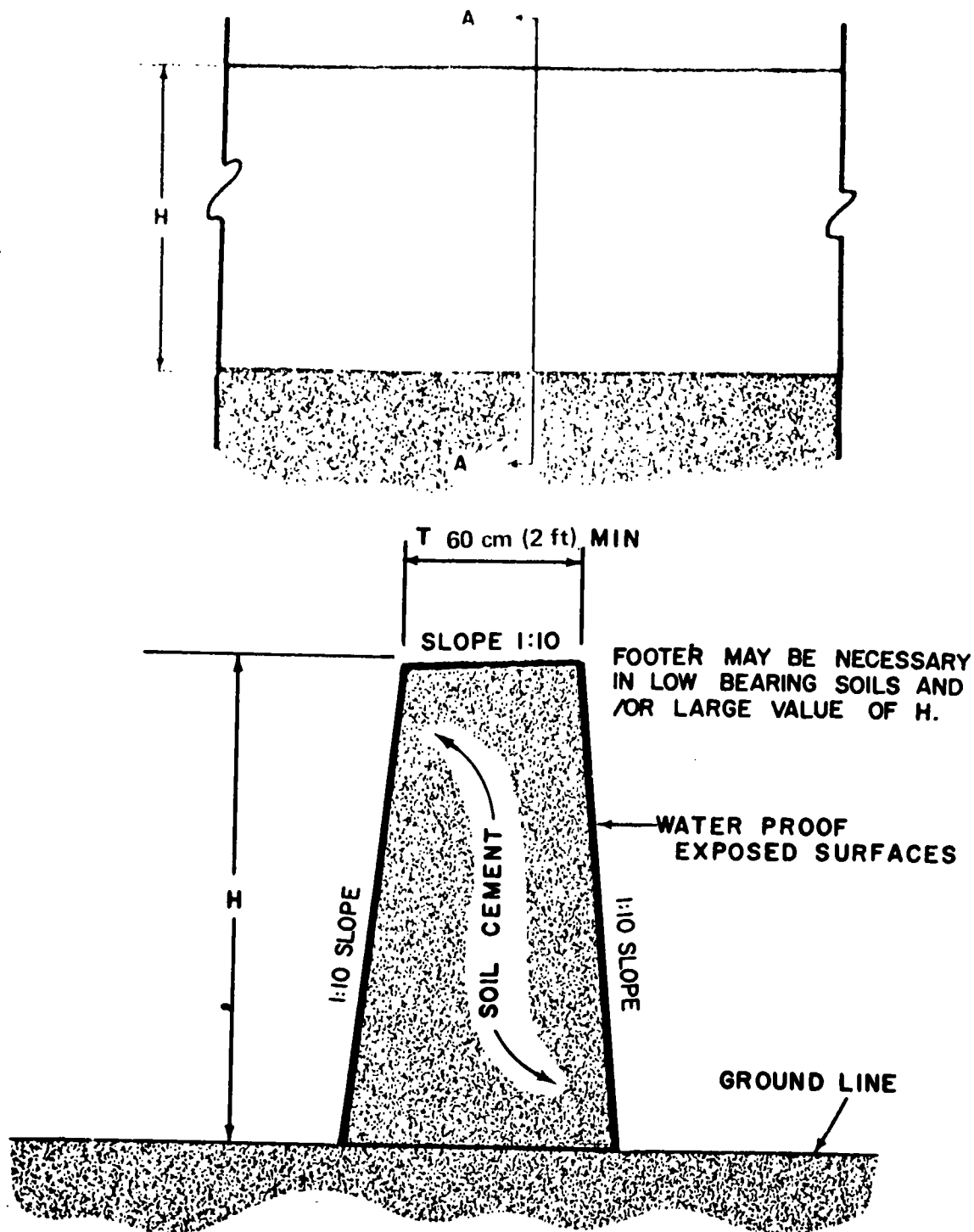
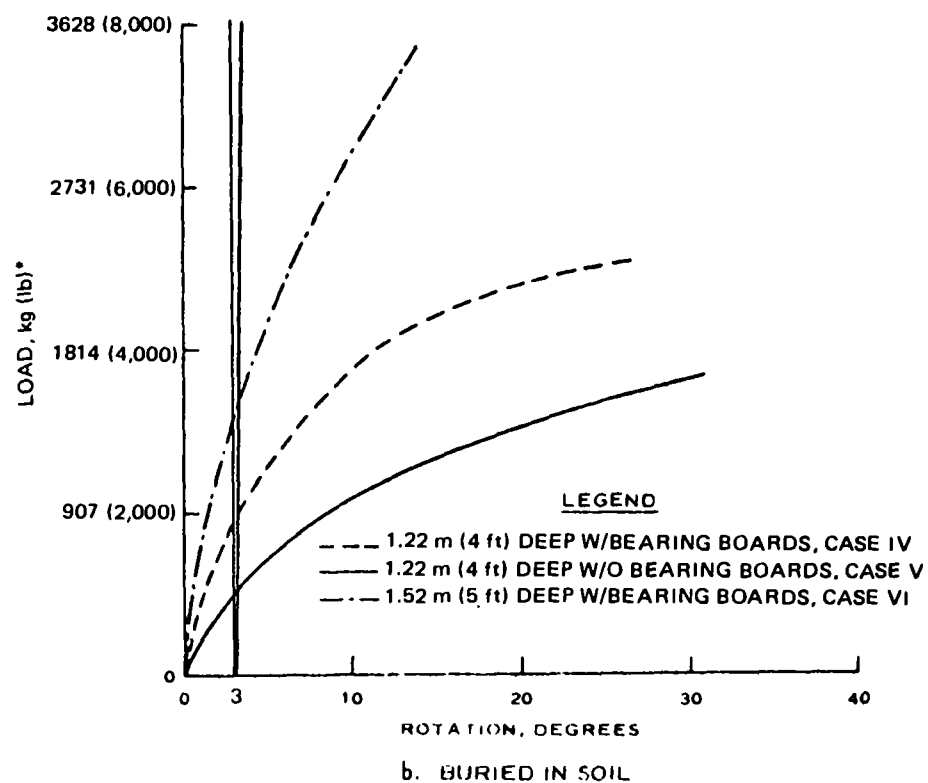
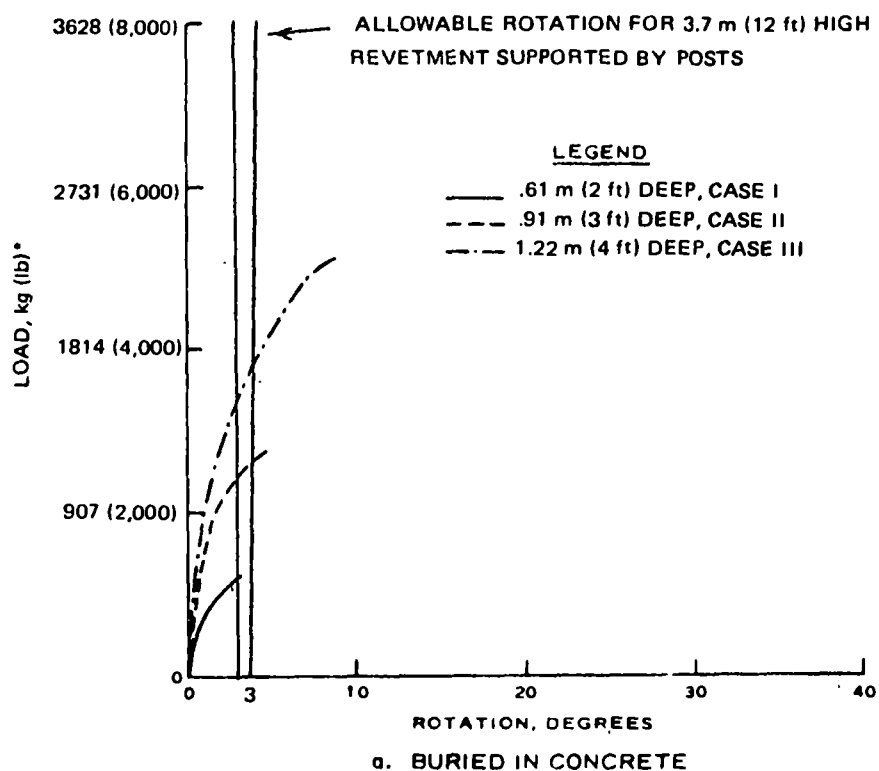


Figure 7-20. Soil cement free-standing wall.



*NOTE: FOR LOAD APPLIED 3.7 m (10 ft) ABOVE GROUND SURFACE

Figure 7-21. Support-post load versus deflection.



CHAPTER 8

MAINTENANCE, REPAIRS, AND IMPROVEMENTS

8-1. Maintenance

a. Earth Structures. Normal deterioration of construction materials exposed to the weather will require regular inspections. Erosion, rot, rust, and poor drainage will reduce the protection which revetments are designed to provide. Timely inspection and repair as required will prevent the need for complete replacement of revetment sections.

b. Inspections. Inspections should include as a minimum:

(1) Inspection of earth cover, before and after rainy seasons or under abnormal weather conditions.

(2) Inspection of wood members, including walls, horizontal and vertical members, for deterioration.

(3) Inspection for loosening of vertical supports in the ground, especially after heavy rains.

(4) Inspection of ditches and pipes to insure they are clean and free of debris. Headwalls should be inspected for settlement or shell damage.

8-2. Repairs

a. Standoff. Since the purpose of the standoff is to detonate shells aimed at the revetments, frequent maintenance or replacement of damaged sections is necessary. Damaged sections should be replaced with prefabricated sections following the procedures outlined in paragraph 7-1.

b. Gravity Revetment. Anchorages shown in construction details provide for deadmen outside the revetment. The steps in replacing a wall section are:

(1) Remove damaged retaining wall section, disconnecting the anchor cable.

(2) Remove all soil that has slumped into the interior of the fortification.

(3) Construct replacement wall sections according to the procedures previously outlined in paragraph 7-3.

(4) Apply waterproofing material to wall.

(5) Raise the new wall section into place and attach the anchor cables.

(6) Backfill new postholes and refill old holes.

(7) Fill voids in backfill with suitable soil and apply cover.

(8) Repair any damage to the drainage system.

c. Earth Revetment. This type of revetment may be repaired as follows:

(1) Remove earth from parking area.

(2) Replace earth displaced from revetment.

(3) Reshape damaged slopes.

(4) Repair waterproof cover or replace sod.

(5) Repair any damage to the drainage system.

d. Bulkhead Revetment. This type of revetment may be repaired as follows:

(1) Remove damaged wall sections, disconnecting the tie cables and redigging the postholes in the damaged area.

(2) Remove all soil that has slumped beyond the wall lines.

(3) Construct replacement wall sections as in the original construction.

(4) Apply waterproofing.

(5) Raise wall sections into place and attach the tie cables and spacer blocks.

(6) Fill postholes.

(7) Fill voids in backfill with suitable soil and apply cover.

(8) Repair any damage to drainage system.

e. Free-Standing Wall. Remove damaged system and replace new section. Repair of concrete is described in TM 5-742.

8-3. Improvements

a. Additional Protection.

(1) Protection provided by aircraft revetments can be increased by adding earth fill and a protective cover to the gravity revetment.

(2) The addition of a steel or wood standoff to the original structure will increase the penetration resistance significantly, without disturbing or altering the original structure.

b. Increasing Structural Resistance. If wet soil was used initially for gravity revetments,

the addition of dry soil, as available, will greatly increase the protective characteristics of the revetment.

c. Modification of Revetments. Bulkhead-type revetments can be changed by using the bulkhead as a retaining wall for an earth revetment to increase the resistance to penetration. This expedient provides a practical means of in-

creasing revetment protection where a standoff cannot be used.

d. Upgrading Structural lift. Reevaluation of the anticipated use may indicate that the serviceability of the revetments should be extended. Permanent-type structures of reinforced concrete or soil cement may be constructed if the necessary materials, skills, and equipment are available.

APPENDIX A

REFERENCES

A-1. Army Regulations (AR)

- 310-25 Dictionary of United States Army Terms
- 310-50 Authorized Abbreviations and Brevity Codes

A-2. Field Manuals (FM)

- 5-15 Field Fortifications
- 5-34 Engineer Field Data
- 5-35 Engineer's Reference and Logistical Data
- 55-15 Transportation Reference Data

A-3. Technical Manuals (TM)

- 5-232 Elements of Surveying
- 5-233 Construction Surveying
- 5-330 Planning and Design of Roads, Airbases, and Heliports in the Theater of Operations
- 5-331A Utilization of Engineer Construction Equipment: Volume A—Earthmoving, Compaction, Grading, and Ditching Equipment.
- 5-331B Utilization of Engineer Construction Equipment: Volume B—Lifting, Loading, and Hauling Equipment
- 5-331C Utilization of Engineer Construction Equipment: Volume C—Rock Crushers, Air Compressors, and Pneumatic Tools.
- 5-331D Utilization of Engineer Construction Equipment: Volume D—Asphalt and Concrete Equipment.
- 5-331E Utilization of Engineer Construction Equipment: Volume E—Engineer special Purpose and Expedient Equipment.
- 5-333 Construction Management
- 5-337 Paving and Surfacing Operations
- 5-742 Masonry and Concrete



APPENDIX B

BALLISTIC DATA

B-1. Condition I

The graphs, figure B-1① through figure B-1⑪, provide detailed ballistic data for different types of ammunition under condition I when no standoff is used. Each graph pertains to one of the eleven types of protective materials discussed.

B-2. Condition II

The graphs, figure B-2① through figure B-2⑪,

provide penetration data under condition II when a steel standoff is used.

B-3. Condition III

The graphs, figure B-3① through figure B-3⑪, provide penetration data under condition III when a wood standoff is used.

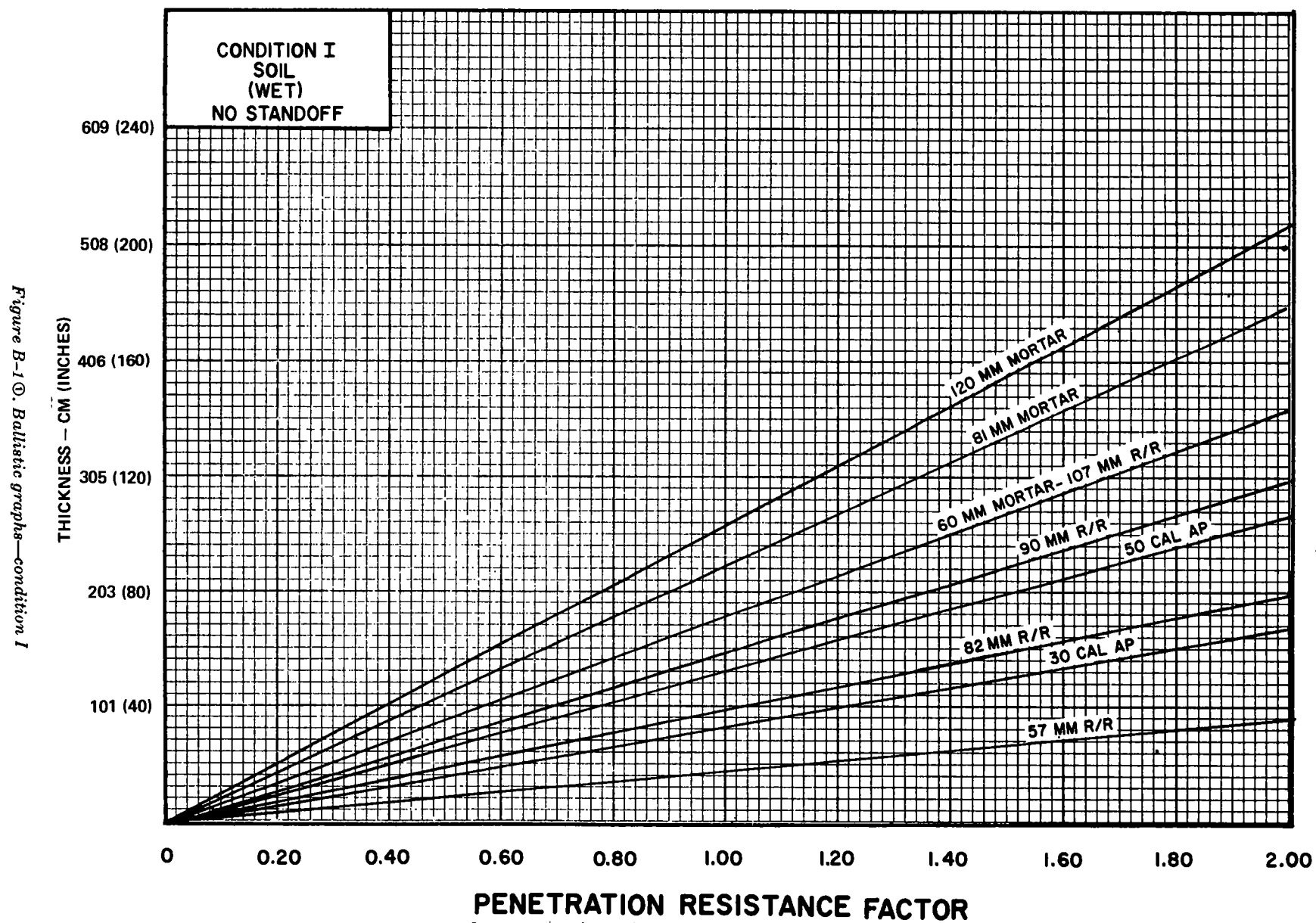


Figure B-1(1). Ballistic graphs -- condition I.

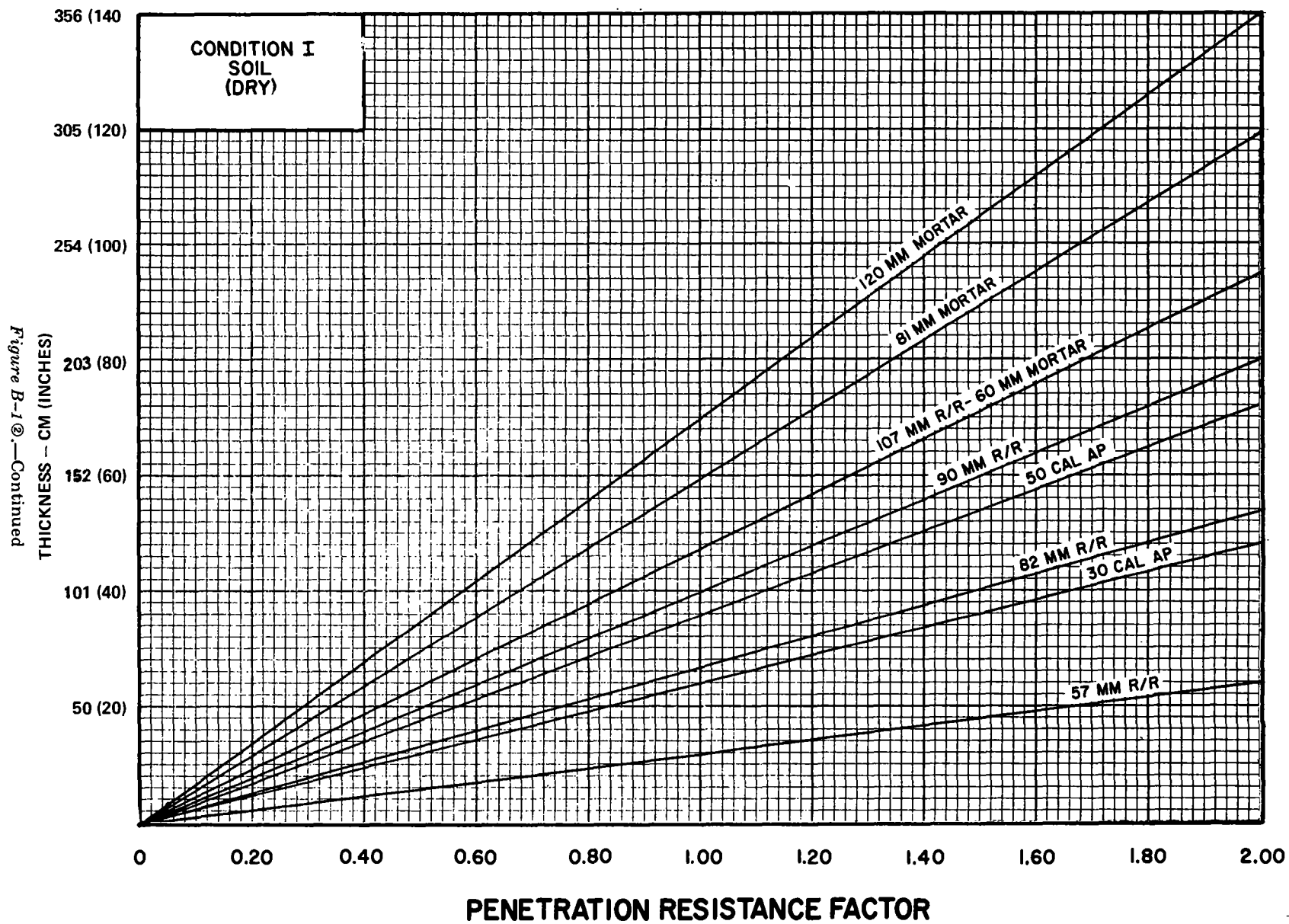


Figure B-1②. —Continued

Figure B-1②. Ballistic graphs -- condition I -- Continued.

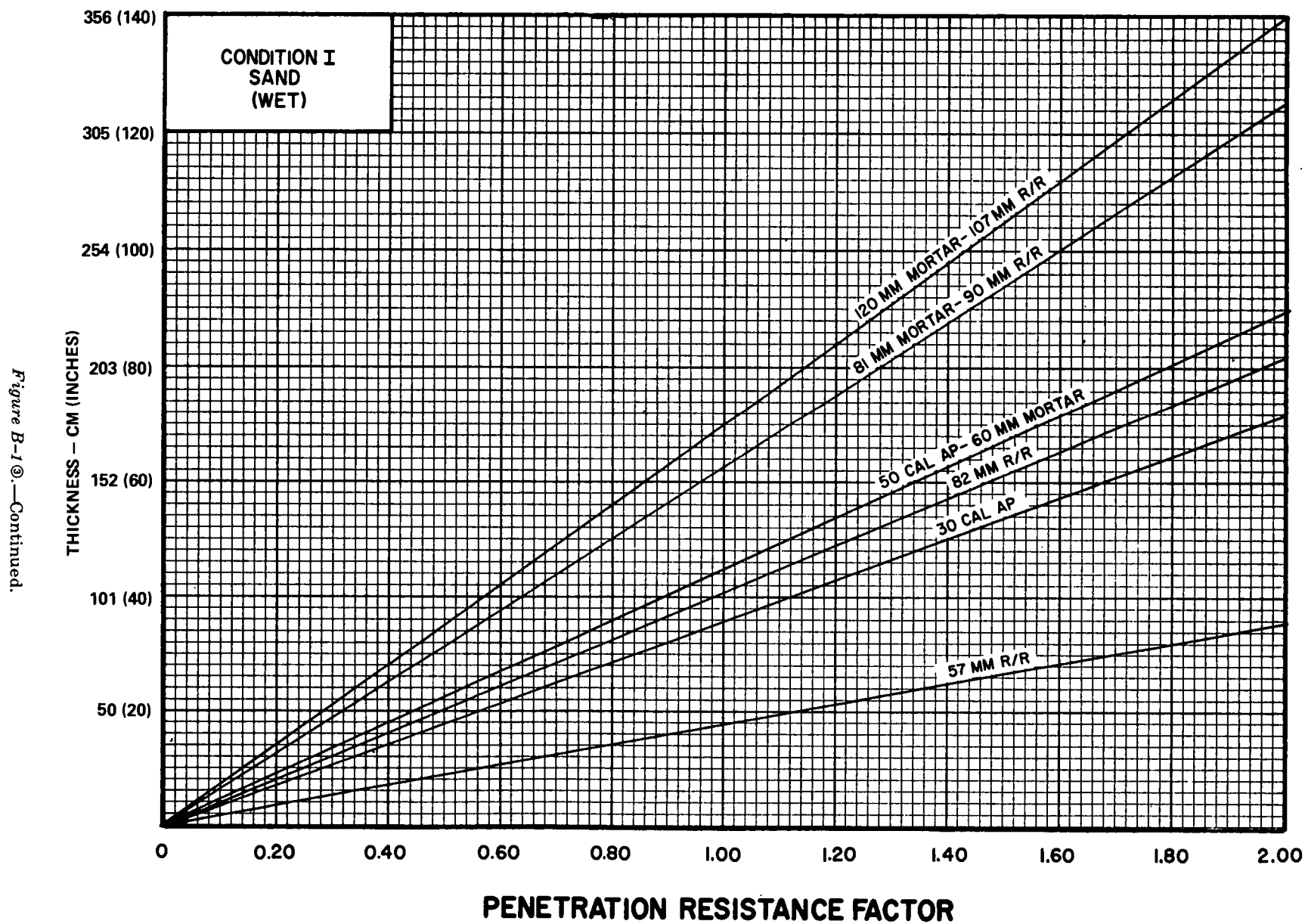


Figure B-1(3). Ballistic graphs -- condition I -- Continued.

Figure B-1 ④—Continued.

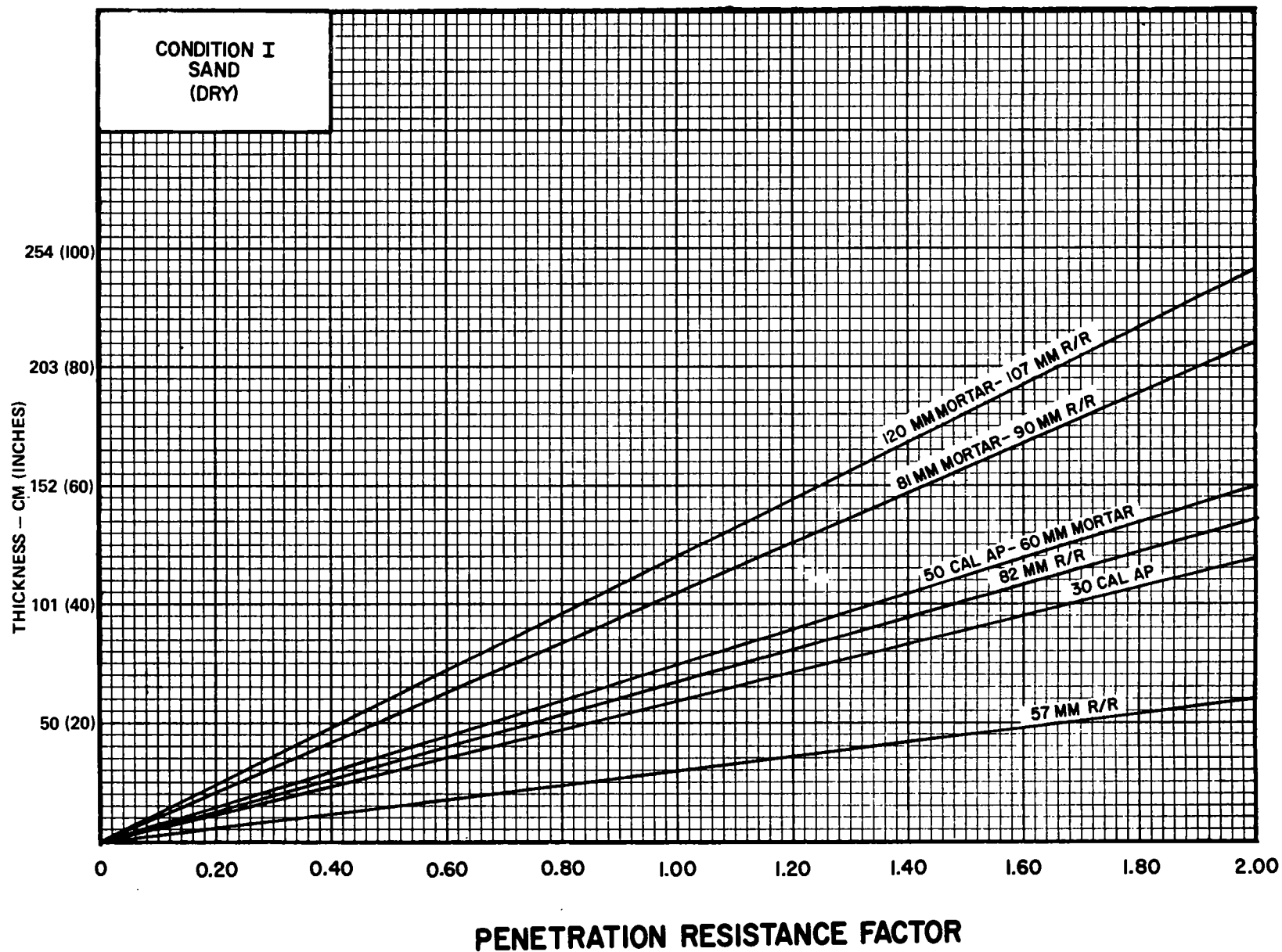


Figure B-1 ④. Ballistic graphs -- condition I -- Continued.

Figure B-1(5)---Continued.

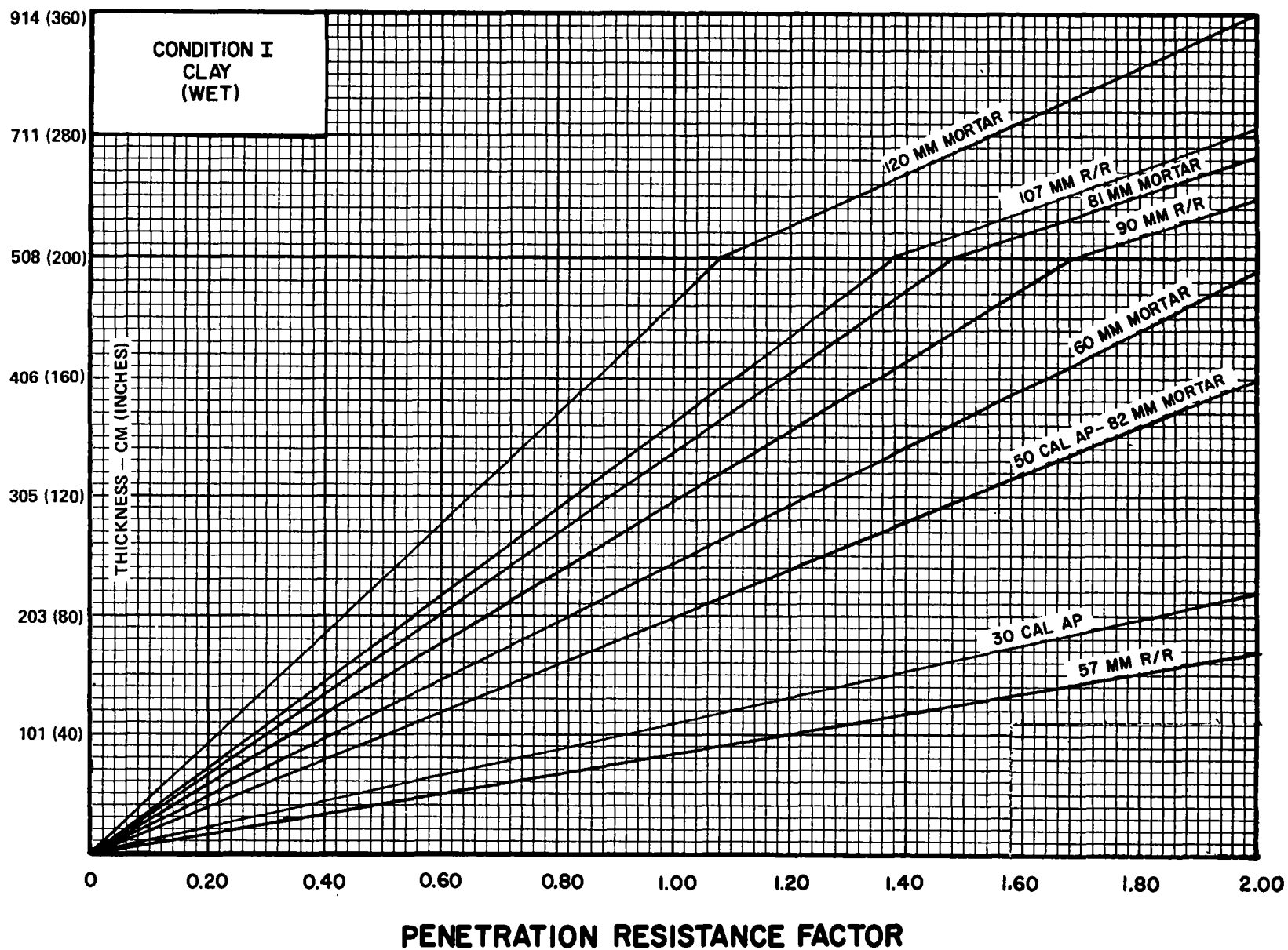


Figure B-1(5). Ballistic graphs -- condition I -- Continued.

Figure B-1 ⑥—Continued.

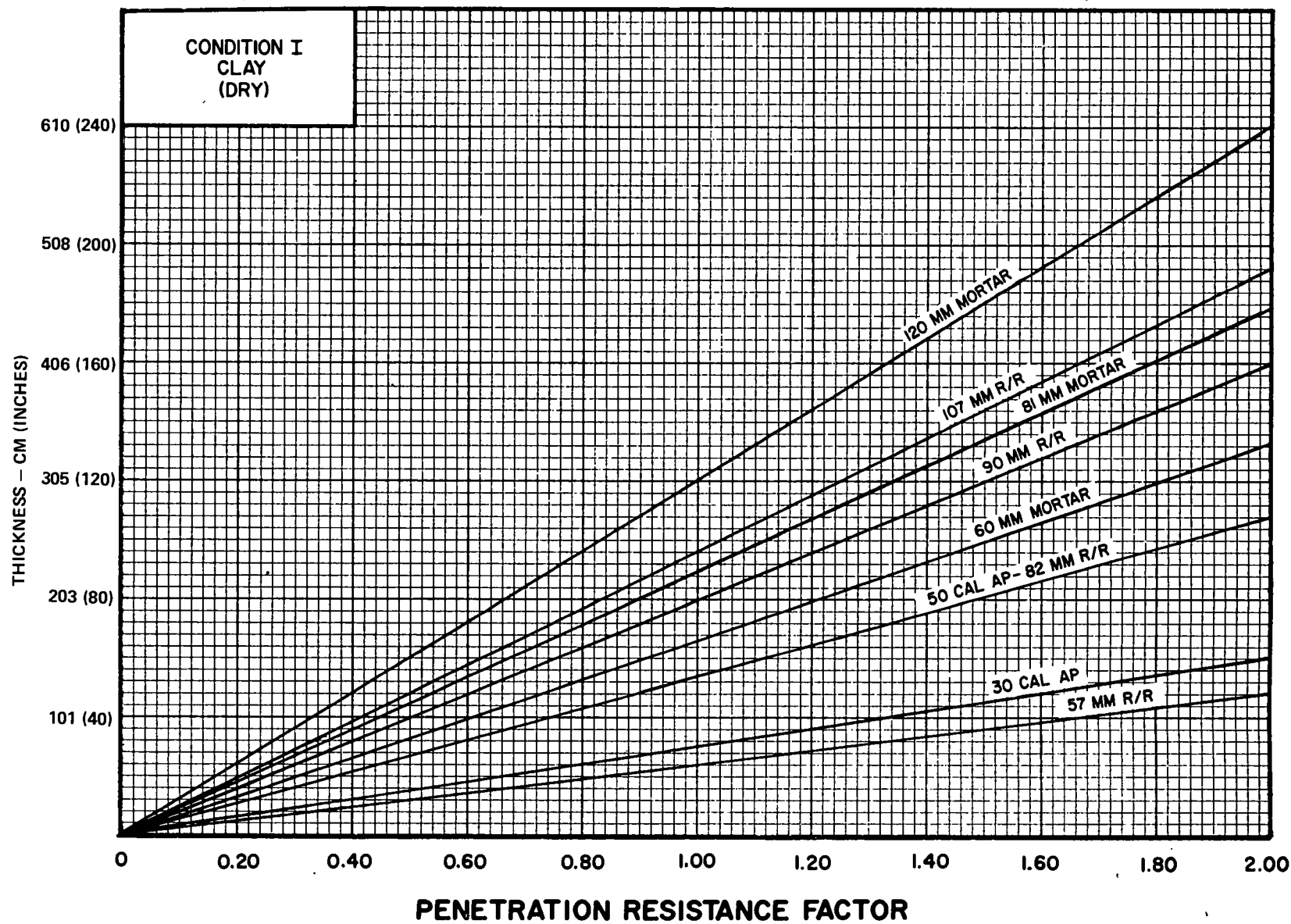


Figure B-1 ⑥. Ballistic graphs -- condition I -- Continued.

Figure B-1⑦—Continued.

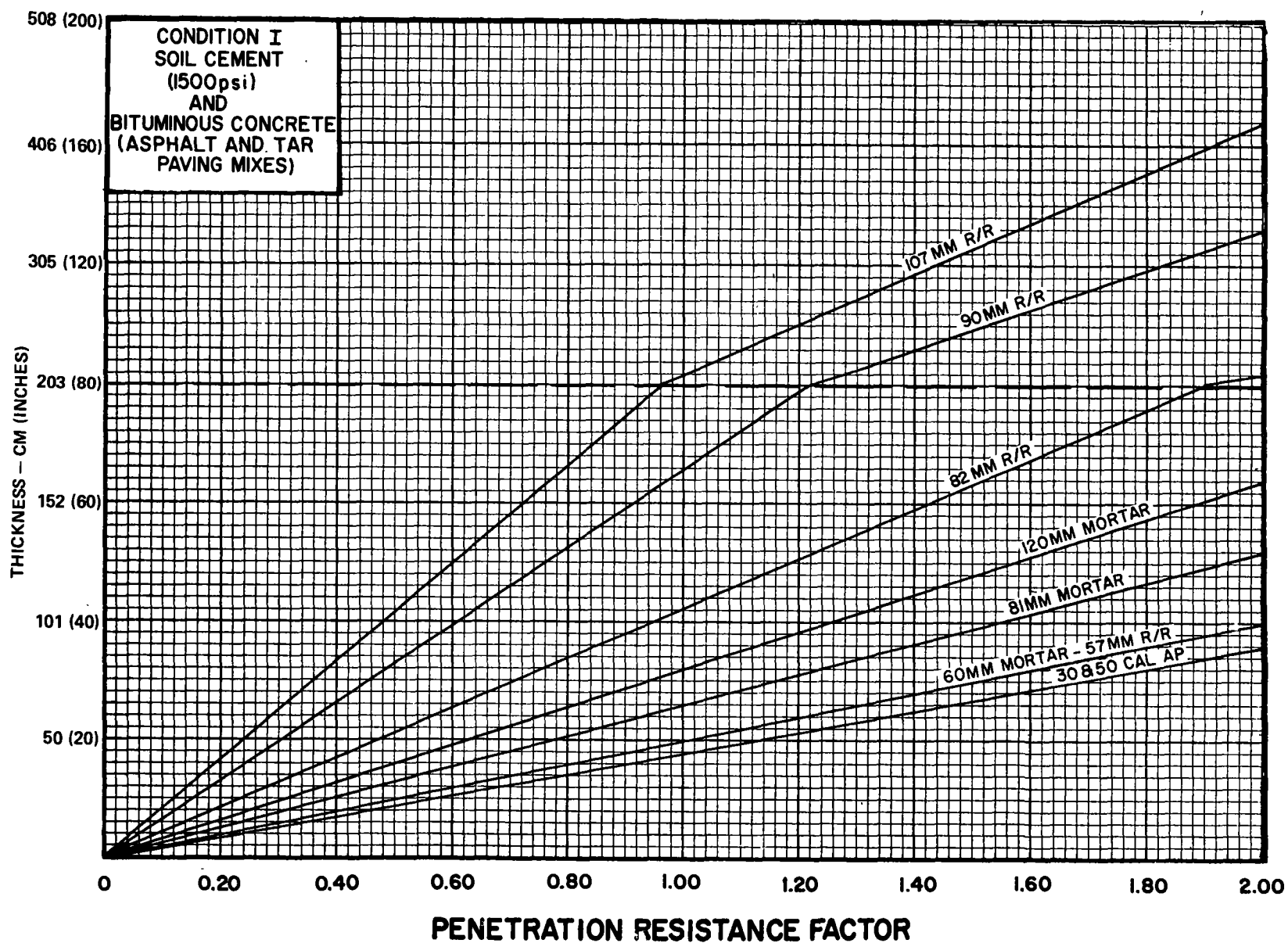


Figure B-1⑦. Ballistic graphs -- condition I -- Continued.

Figure B-1⑧--Continued.

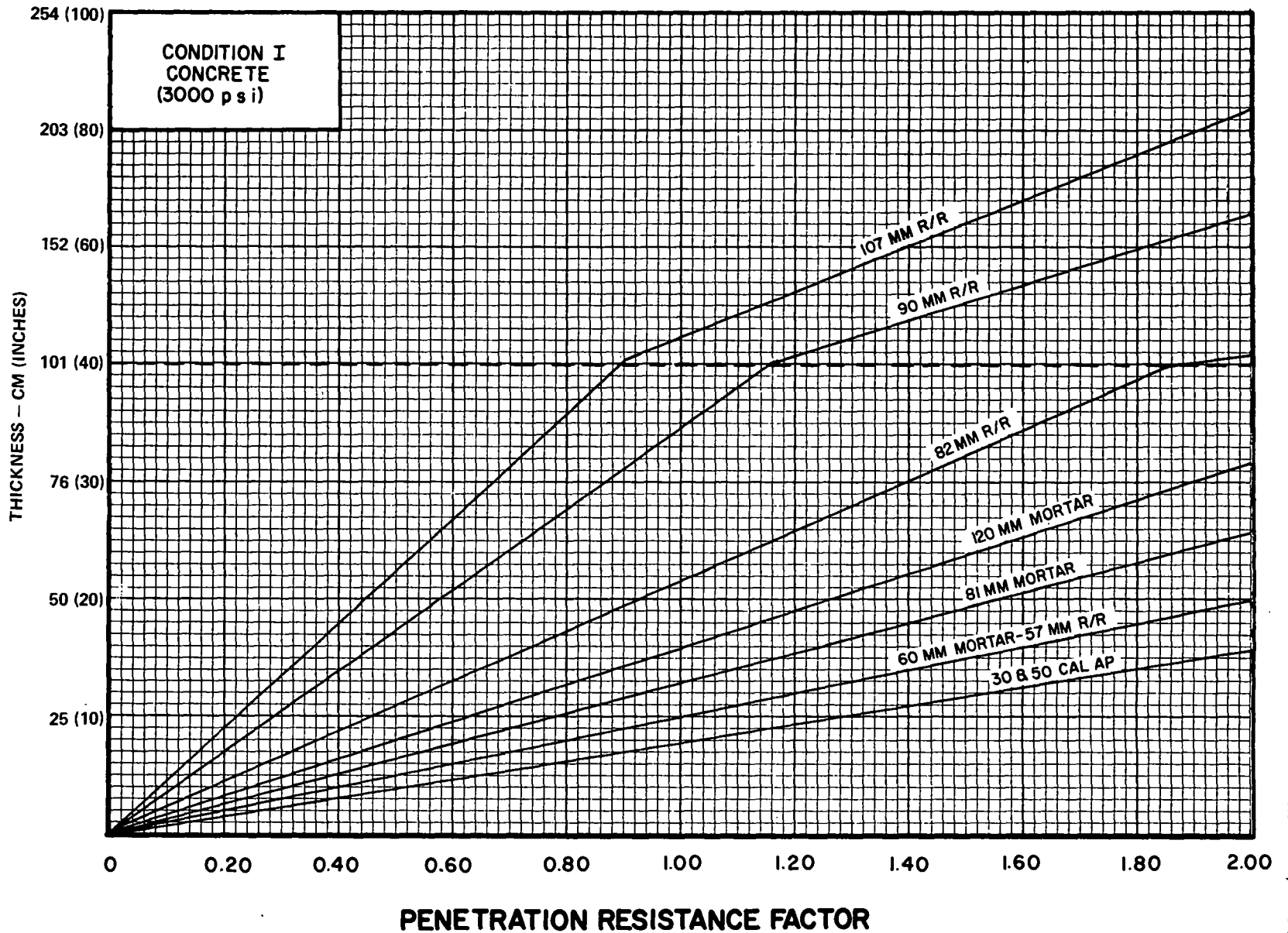


Figure B-1⑧. Ballistic graphs -- condition I -- Continued.

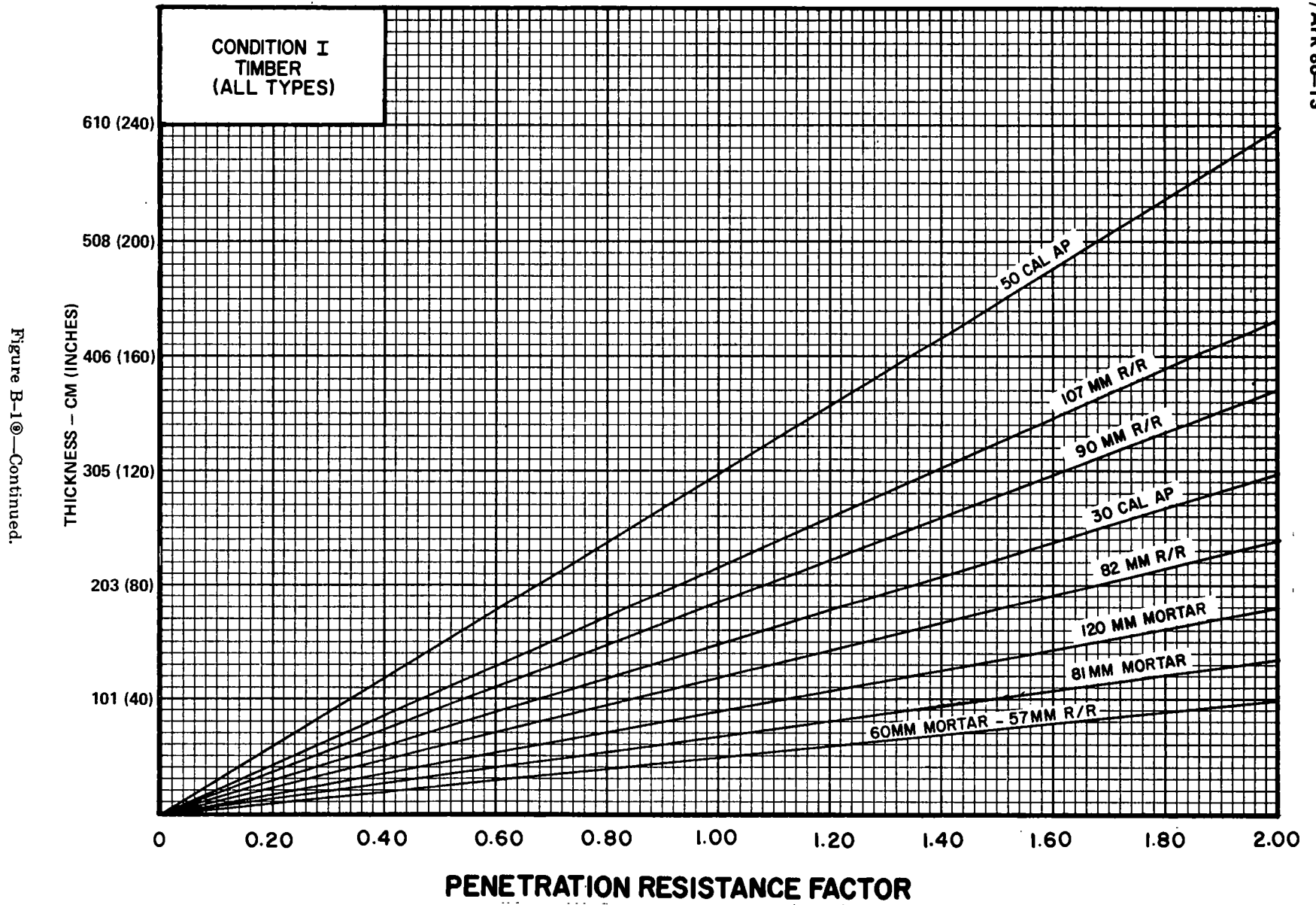


Figure B-1(9). Ballistic graphs -- condition I -- Continued.

Figure B-1@--Continued.

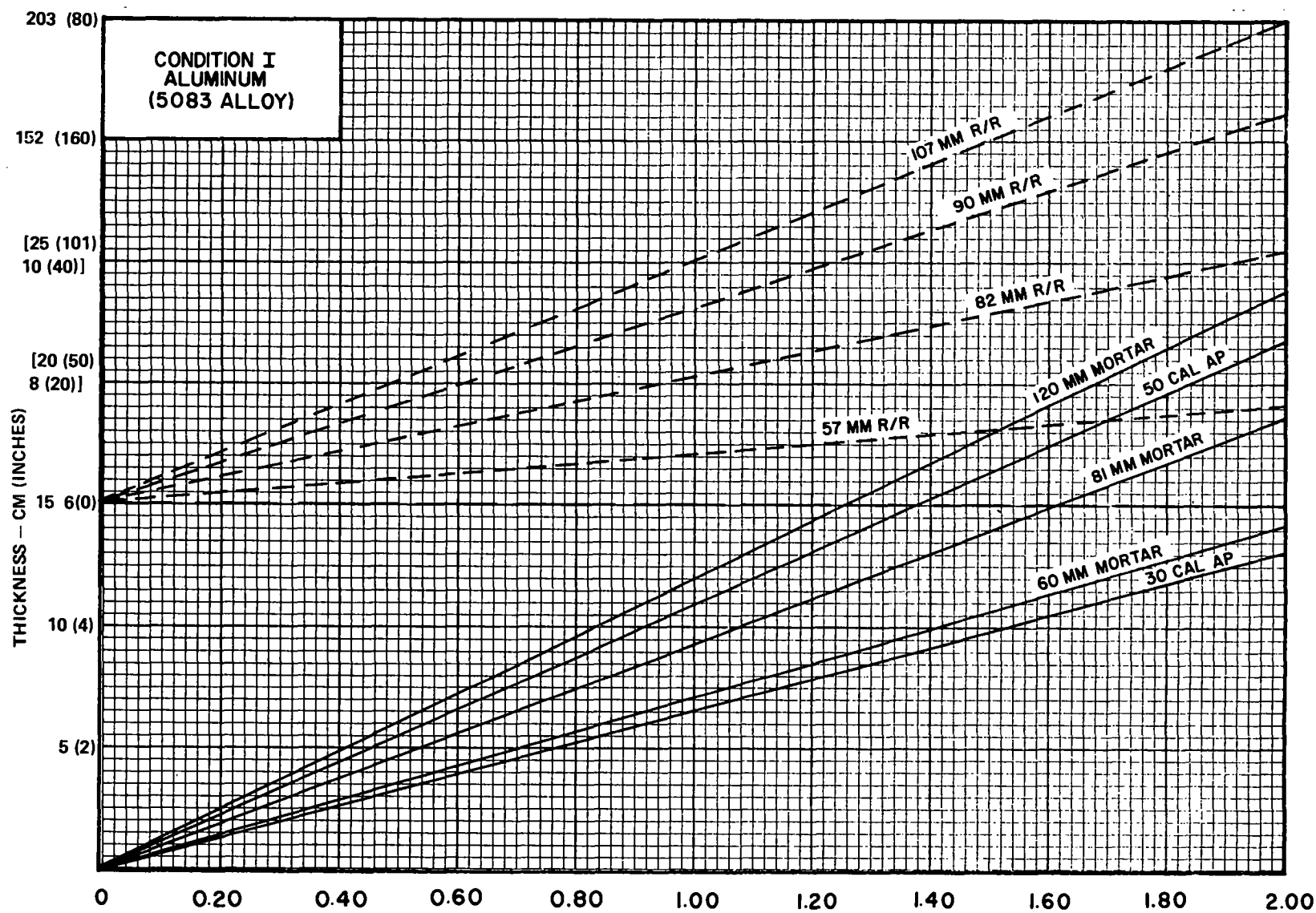


Figure B-1 (10). Ballistic graphs -- condition I -- Continued.

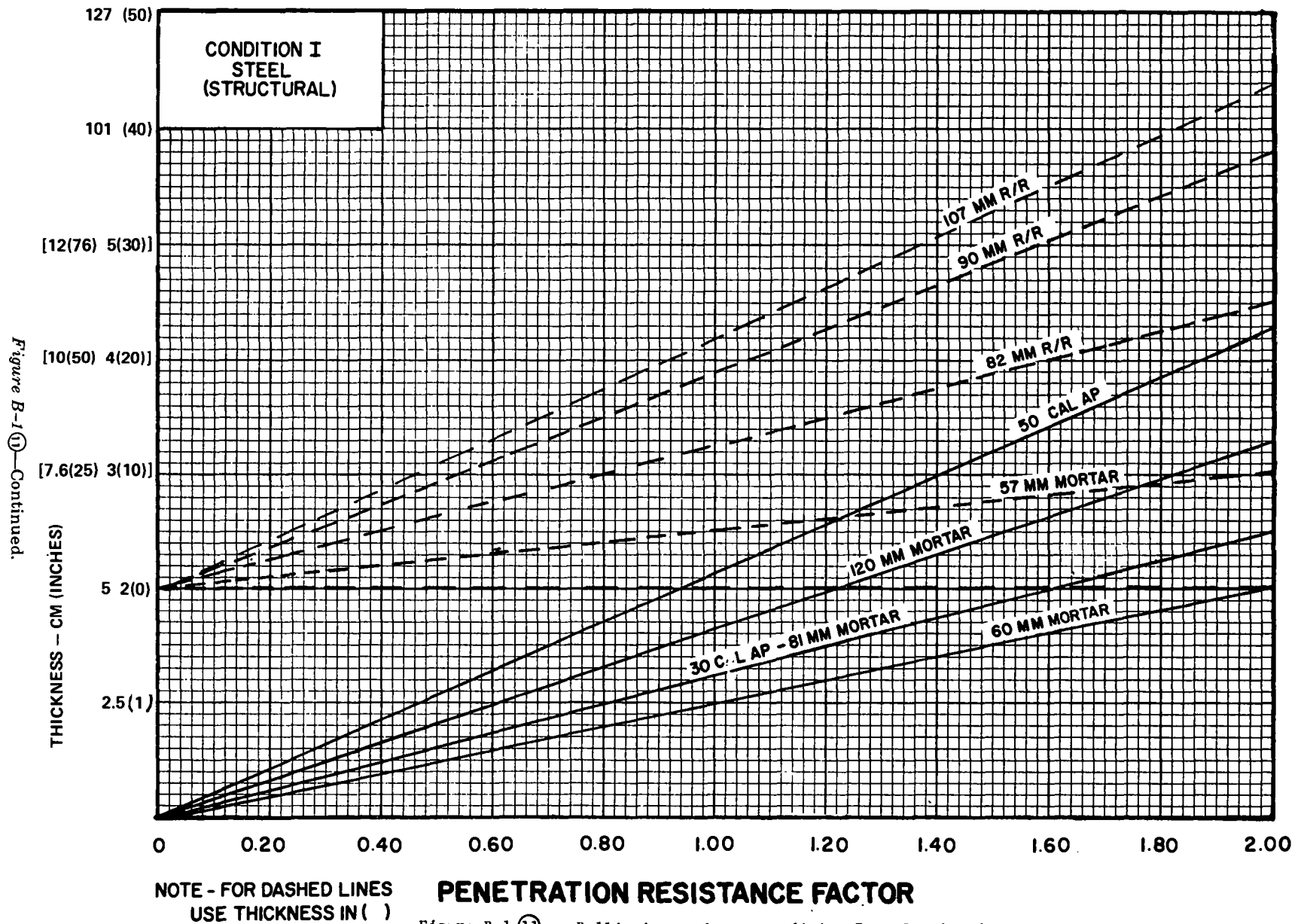


Figure B-2 ① Ballistic graphs—condition II.

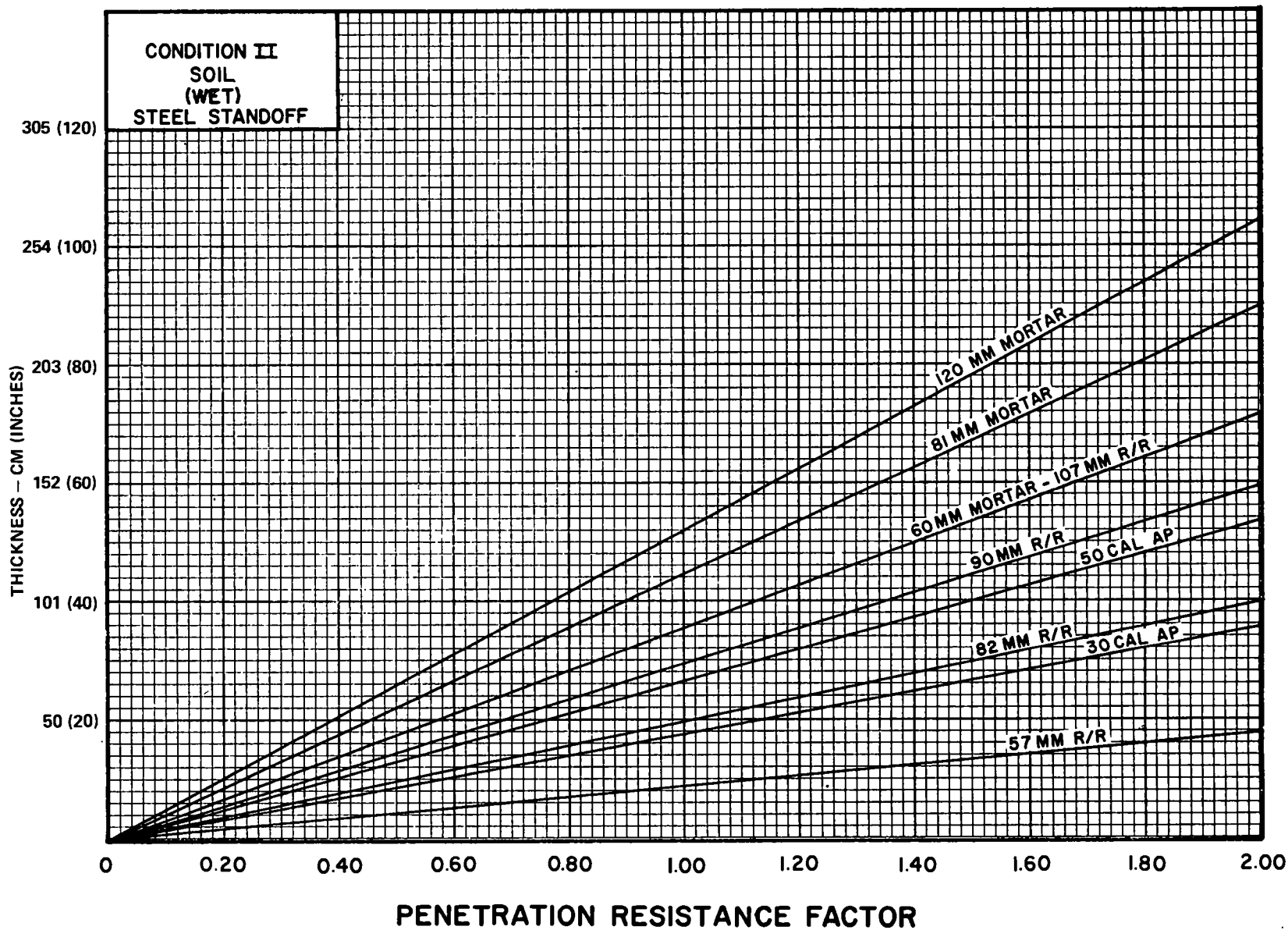


Figure B-2 ①. Ballistic graphs -- condition II.

Figure B-2②—Continued.

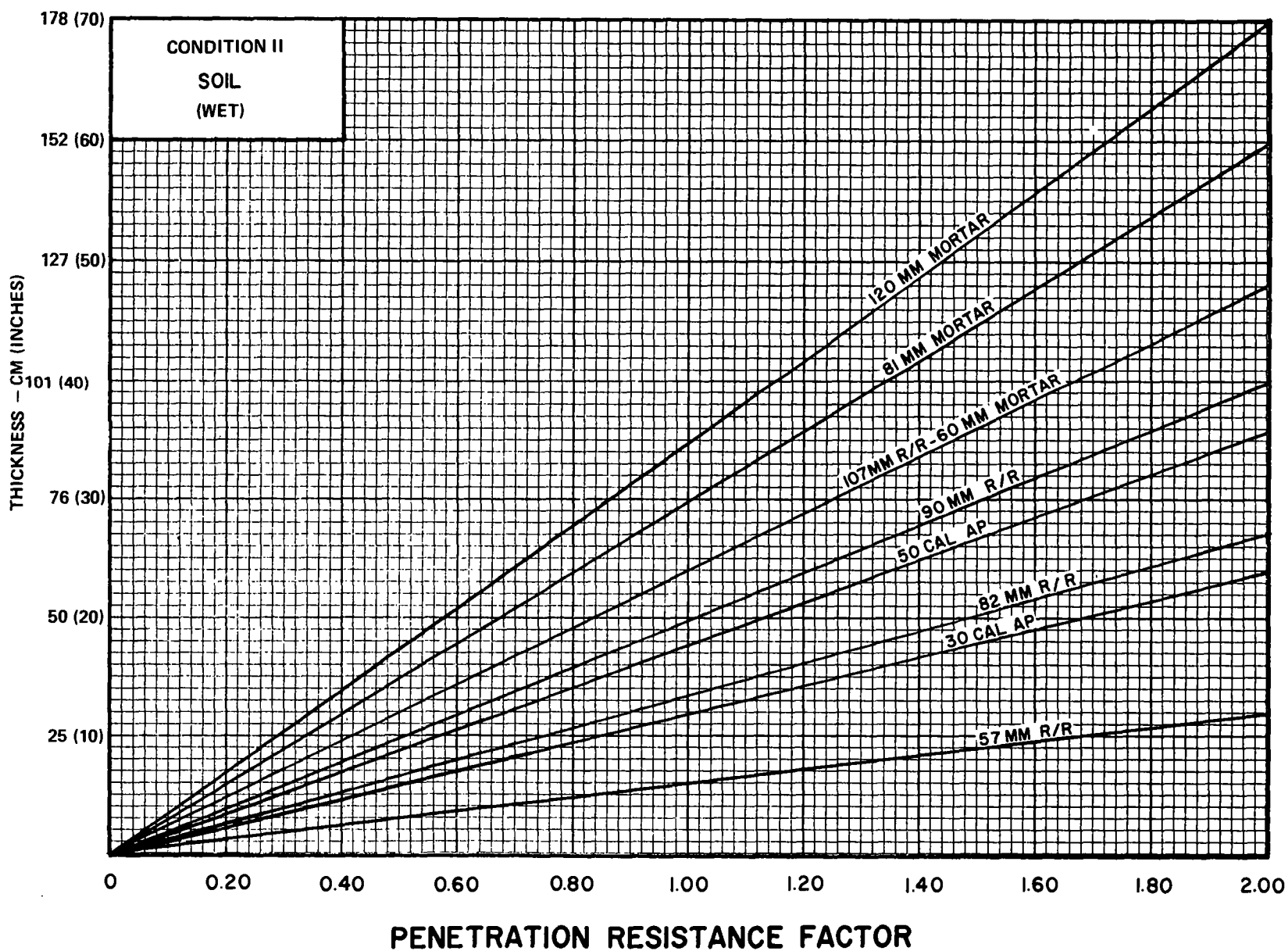


Figure B-2②. Ballistic graphs -- condition II -- Continued.

Figure B-2③--Continued.

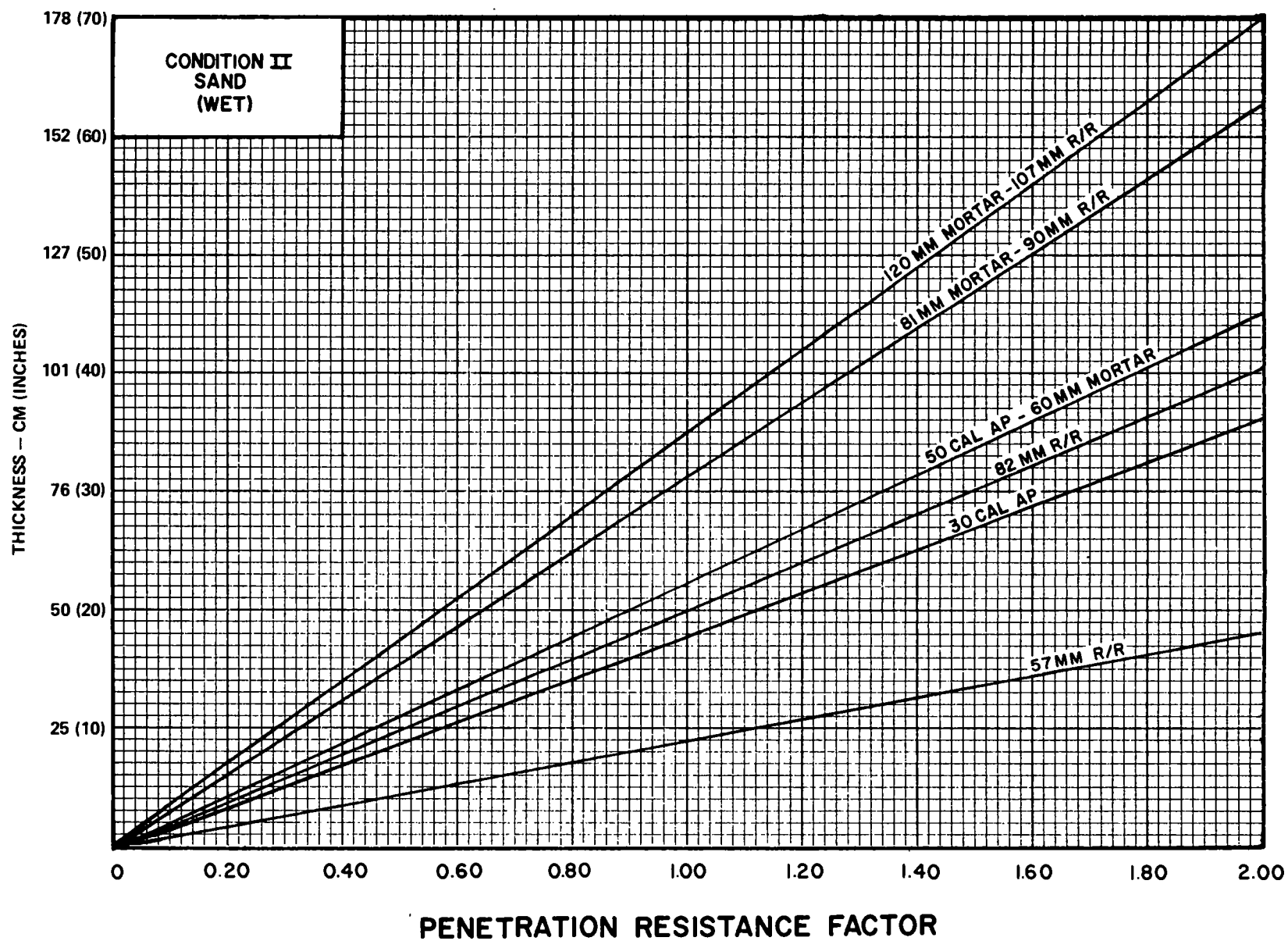


Figure B-2③. Ballistic graphs -- condition II -- Continued.

Figure B-2④—Continued.

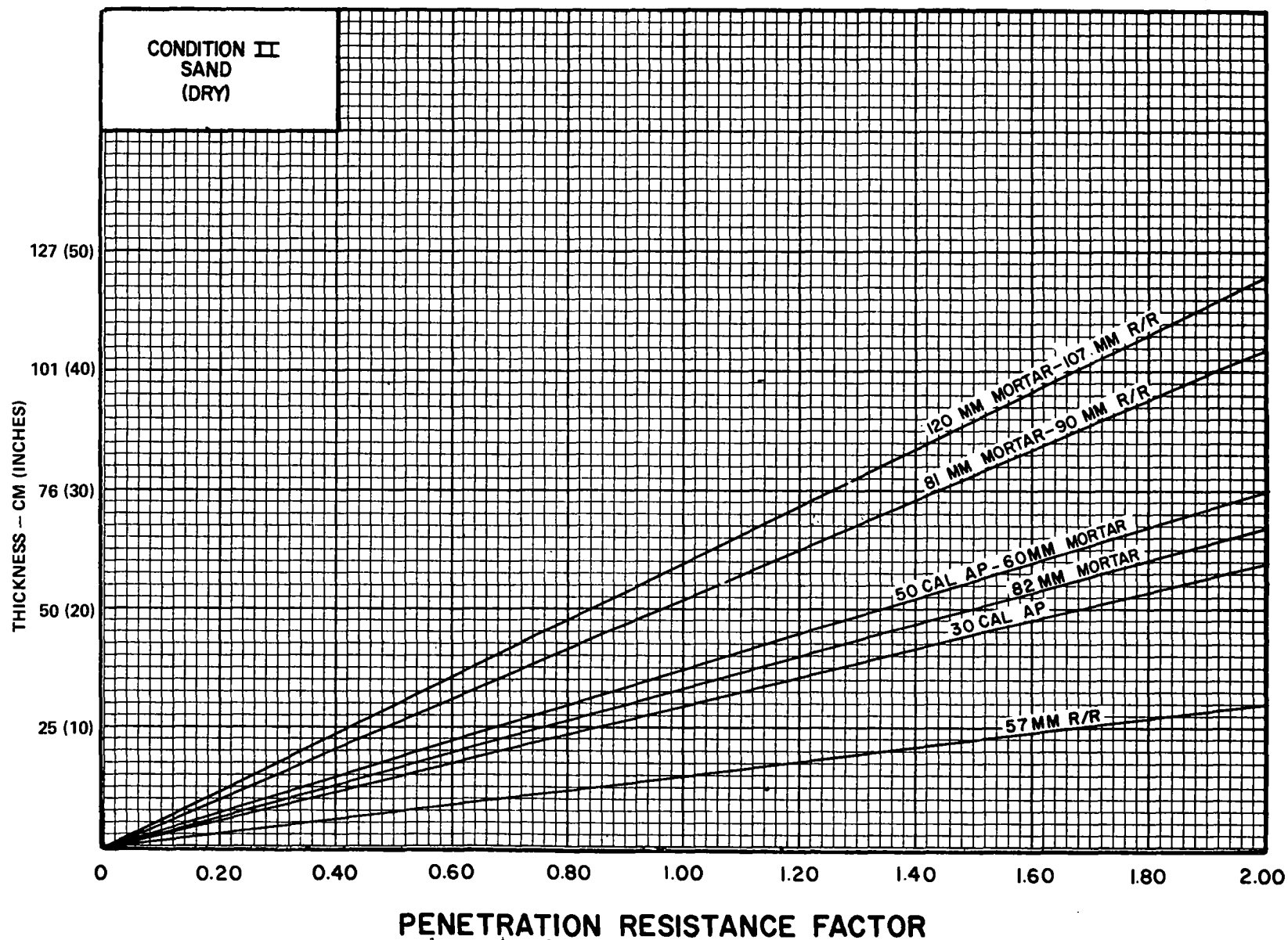


Figure B-2④. Ballistic graphs -- condition II -- Continued.

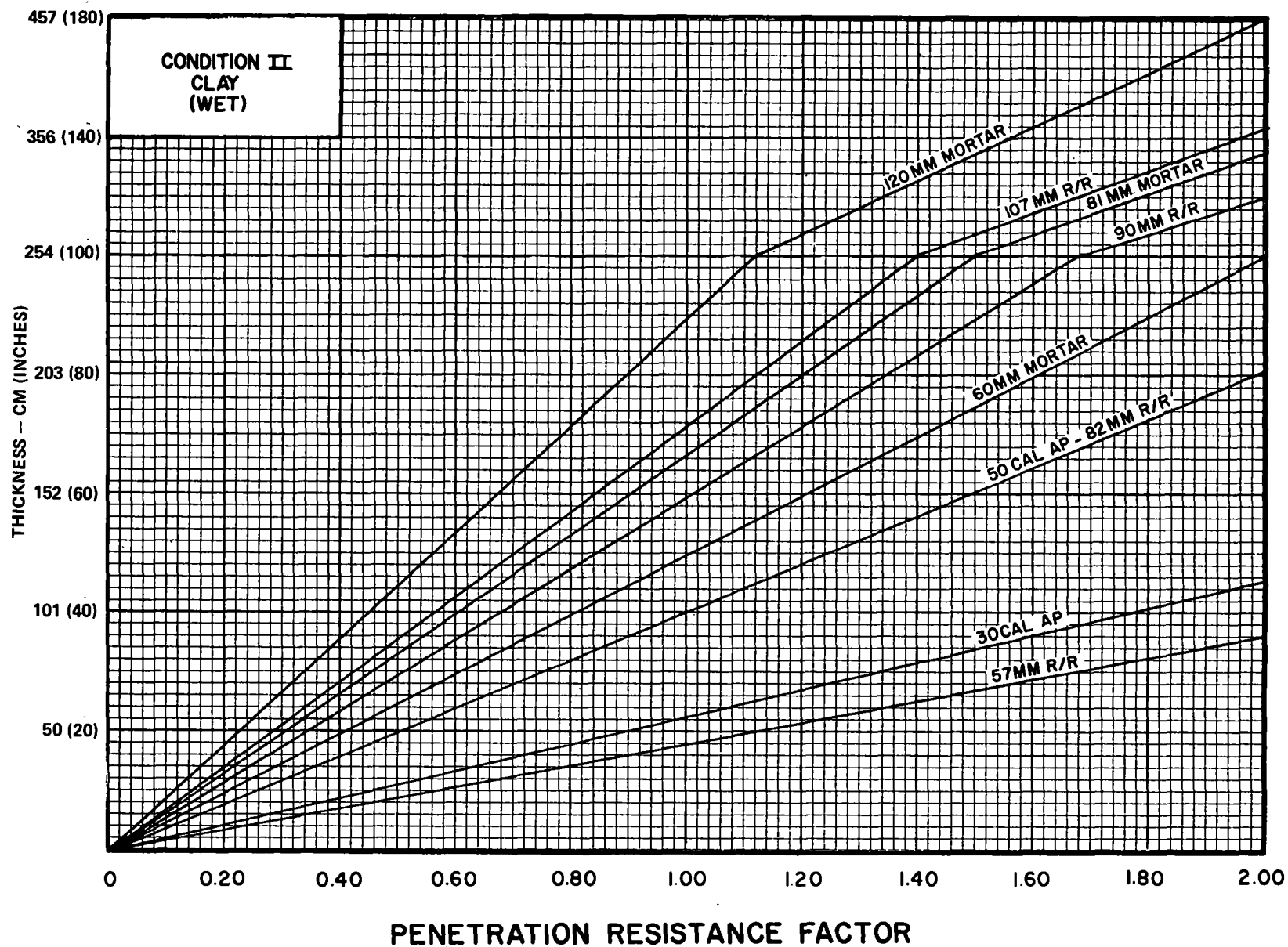


Figure B-2(5). Ballistic graphs -- condition II -- Continued.

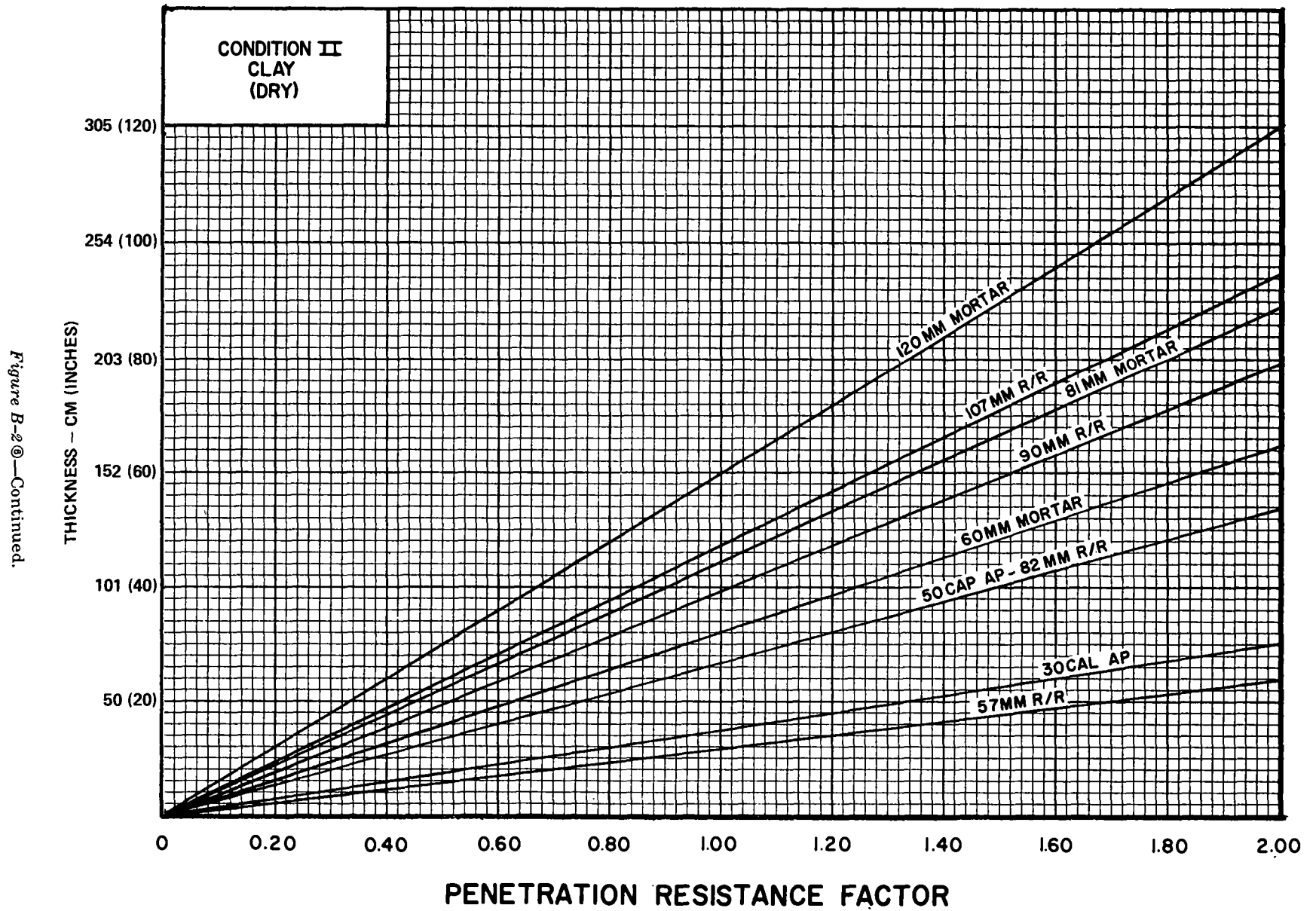


Figure B-2(6). Ballistic graphs -- condition II -- Continued.

Figure B-2⑦--Continued.

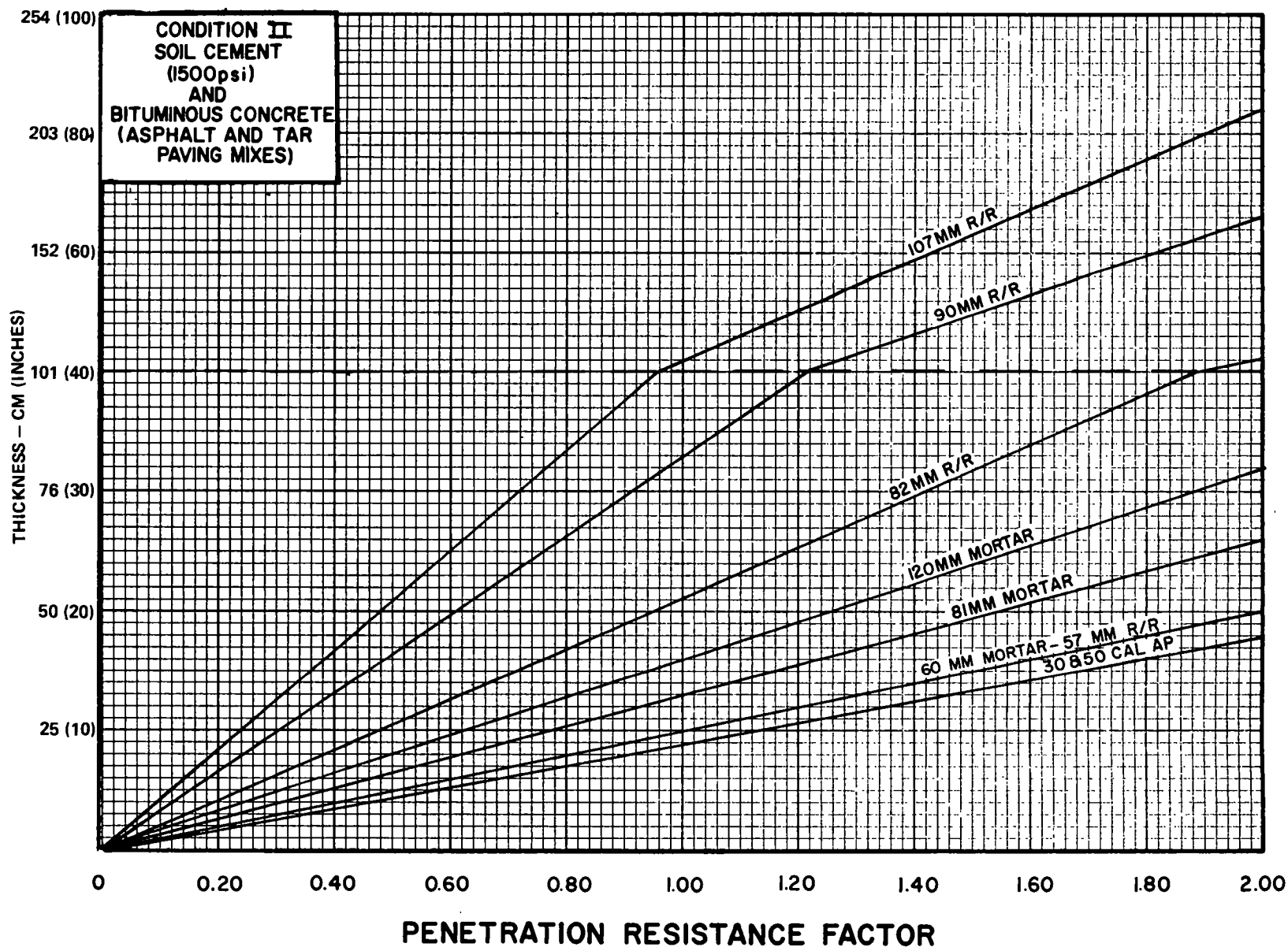


Figure B-2⑦. Ballistic graphs -- condition II -- Continued.

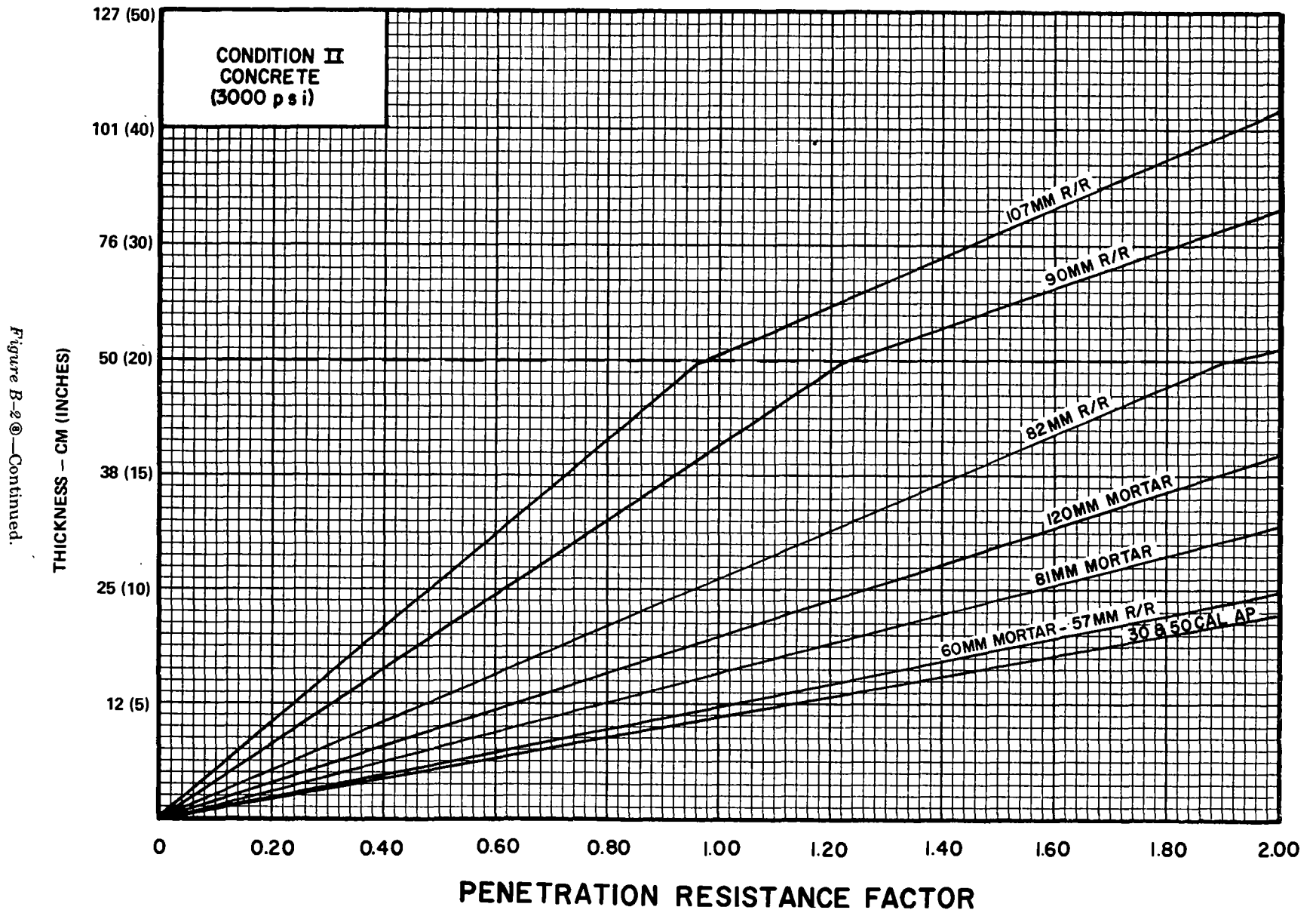


Figure B-2(8). Ballistic graphs -- condition II -- Continued.

Figure B-2(9) — Continued.

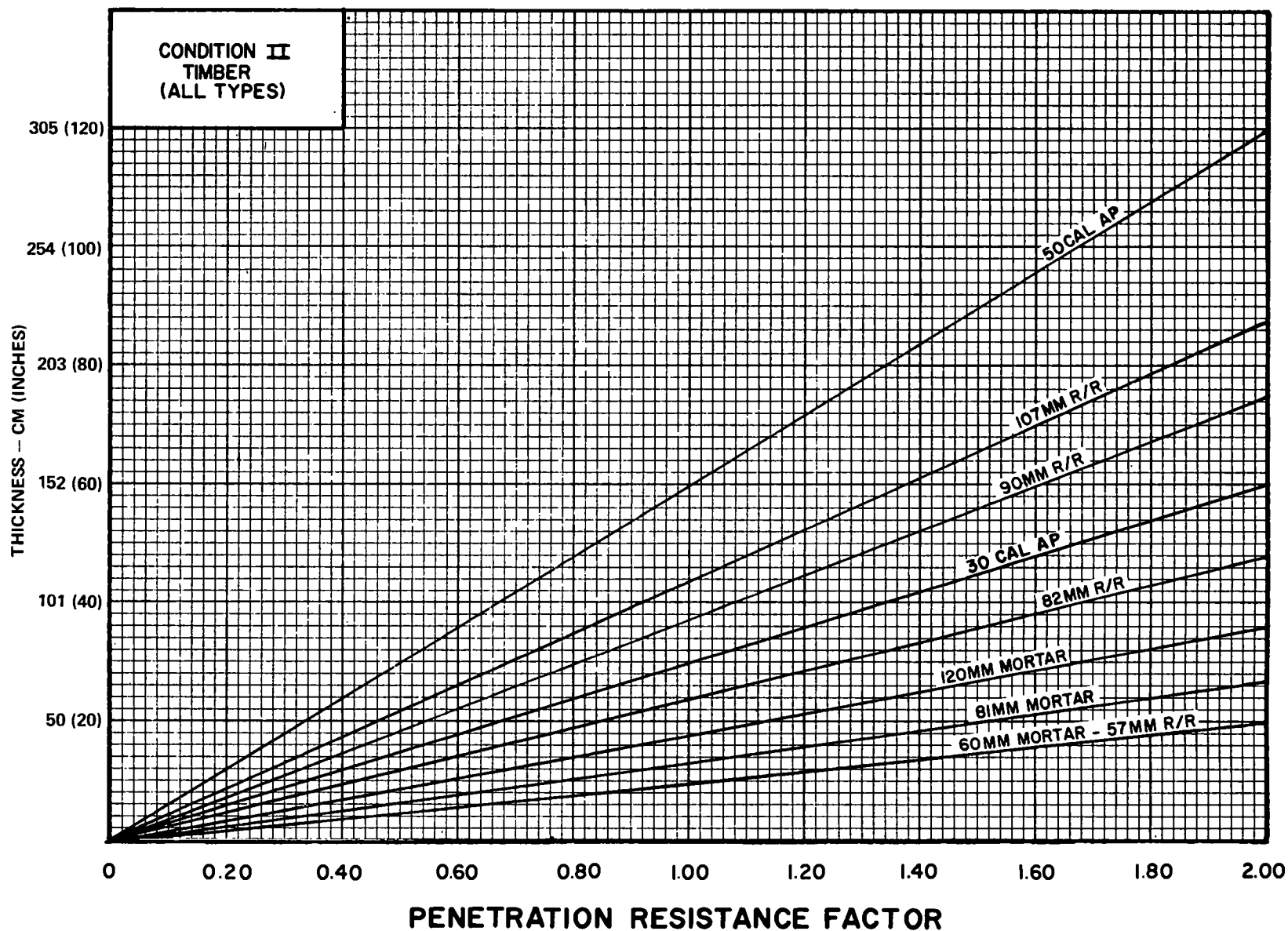


Figure B-2(9). Ballistic graphs -- condition II -- Continued.

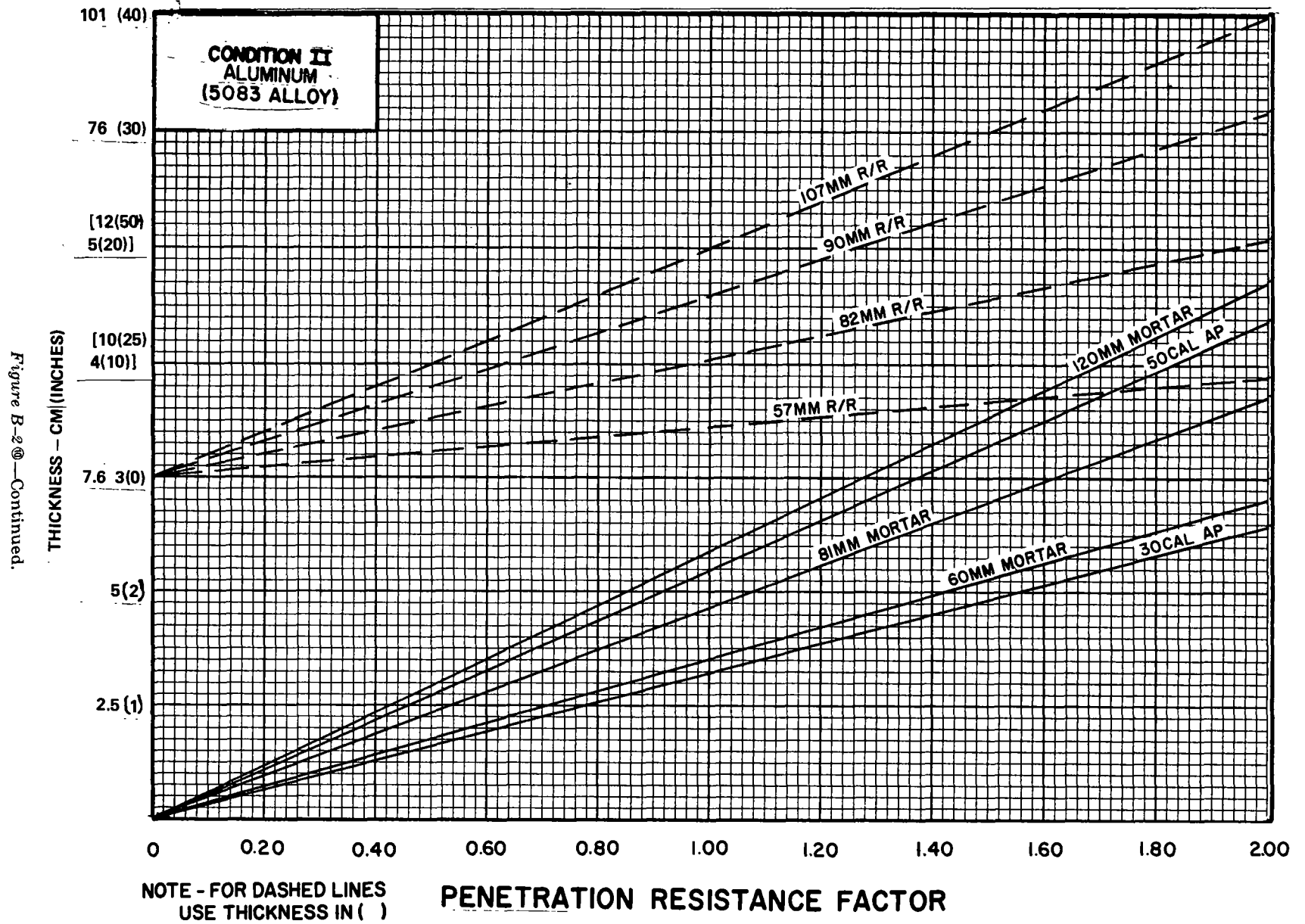
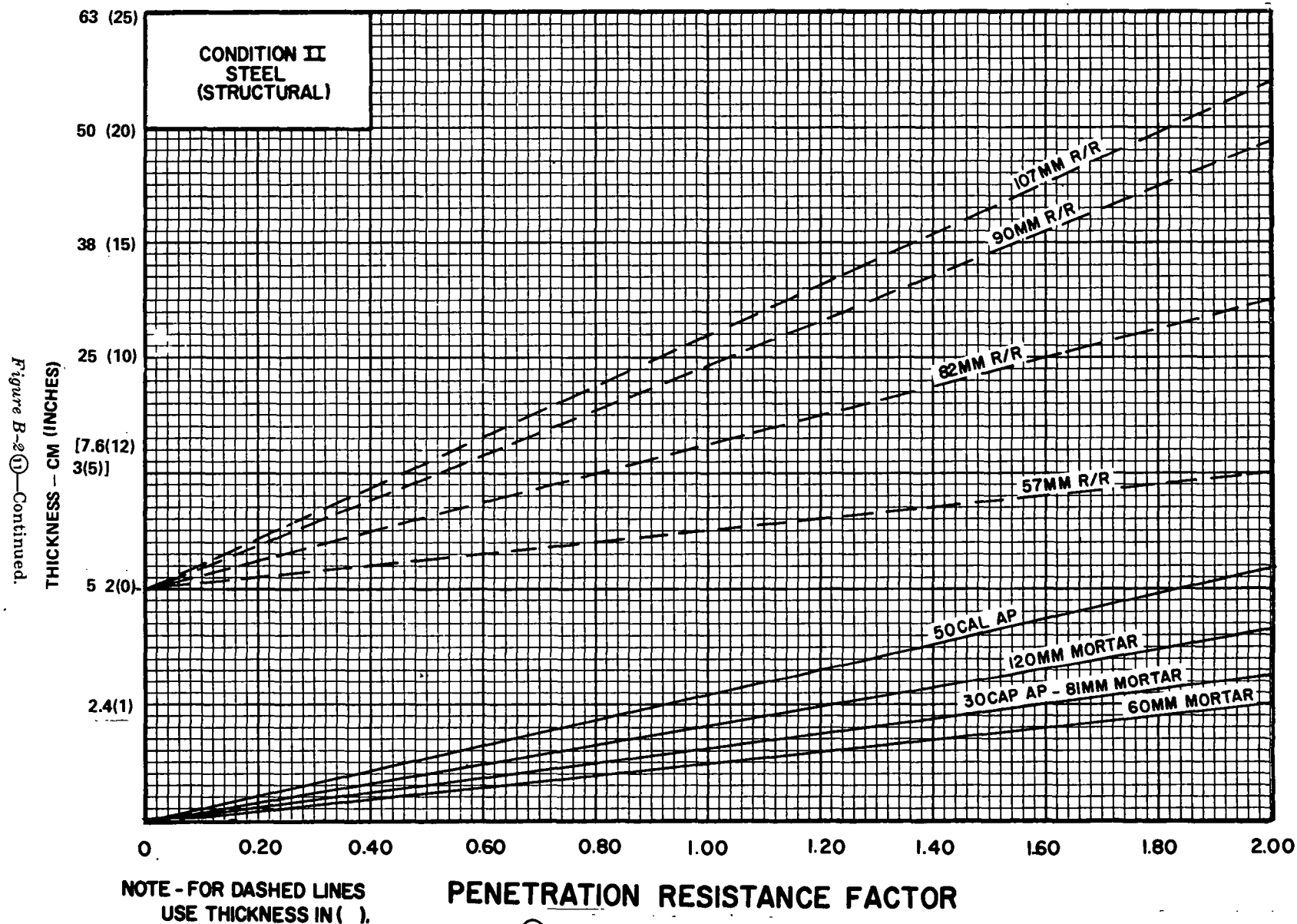


Figure B-2®—Continued.

Figure B-2 (10). Ballistic graphs -- condition II -- Continued.



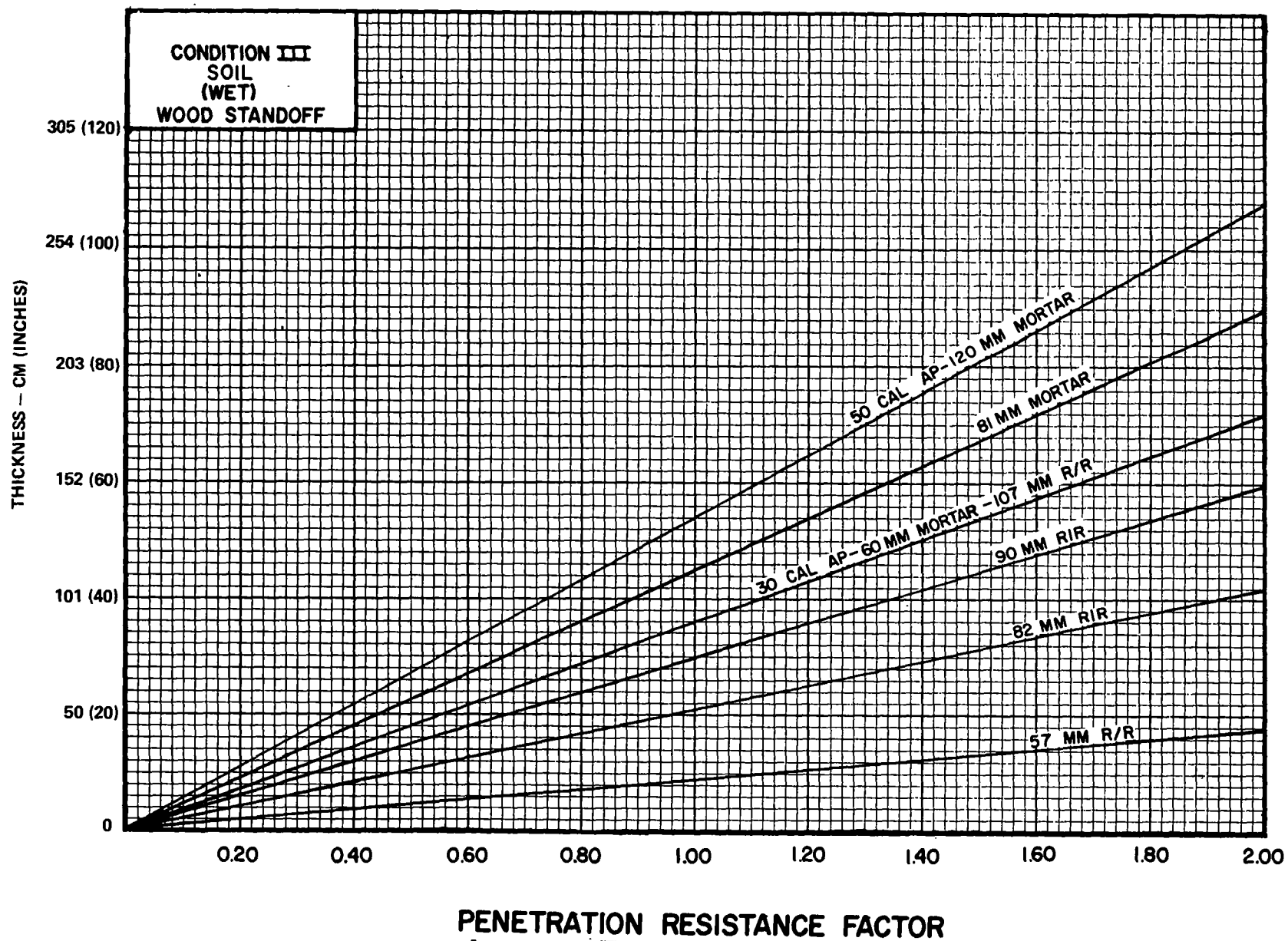


Figure R-3(1). Ballistic graphs -- condition III.

Figure B-3(1). Ballistic graphs--condition III.

Figure B-3②—Continued.

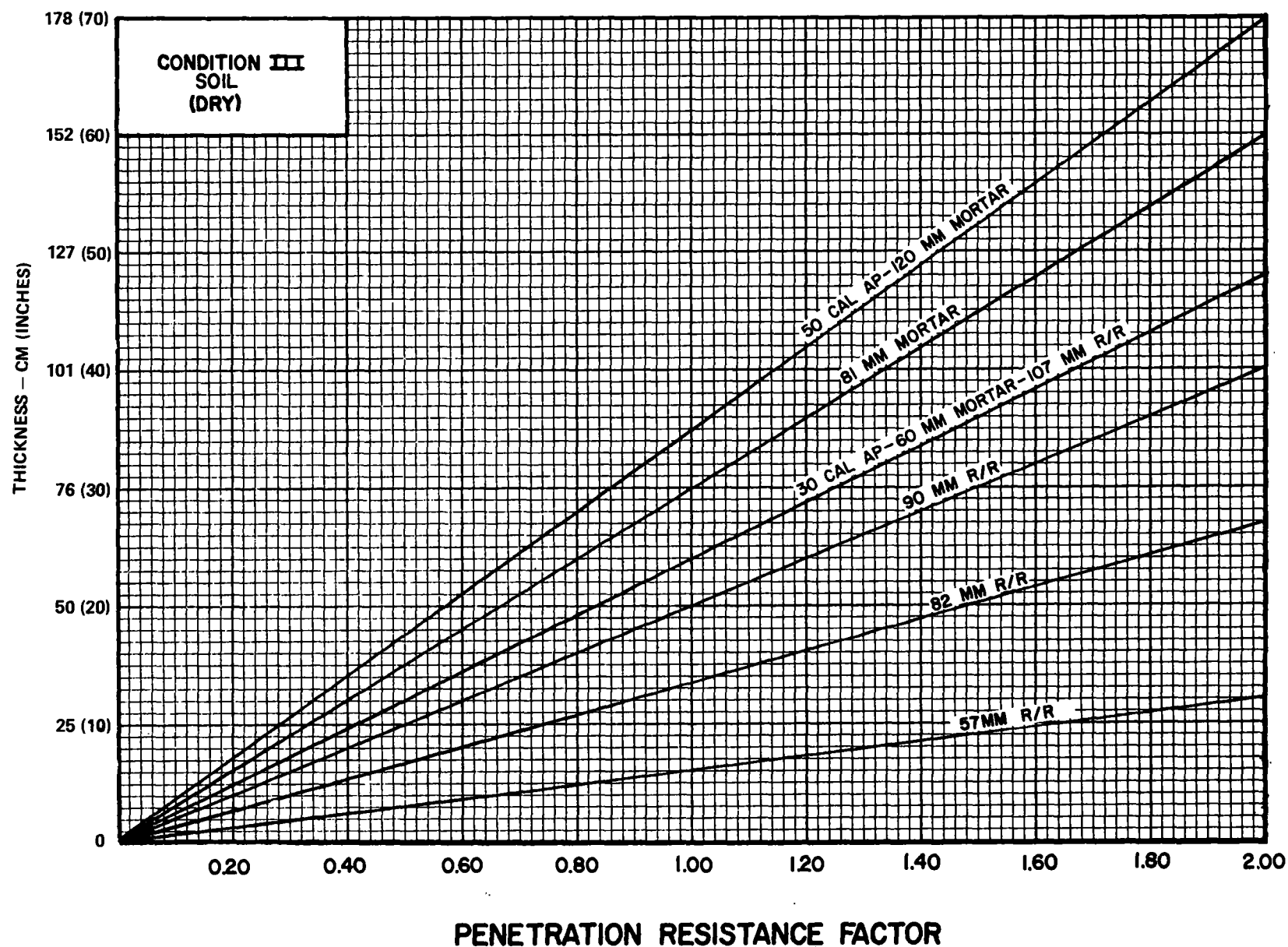


Figure B-3②. Ballistic graphs -- condition III -- Continued.

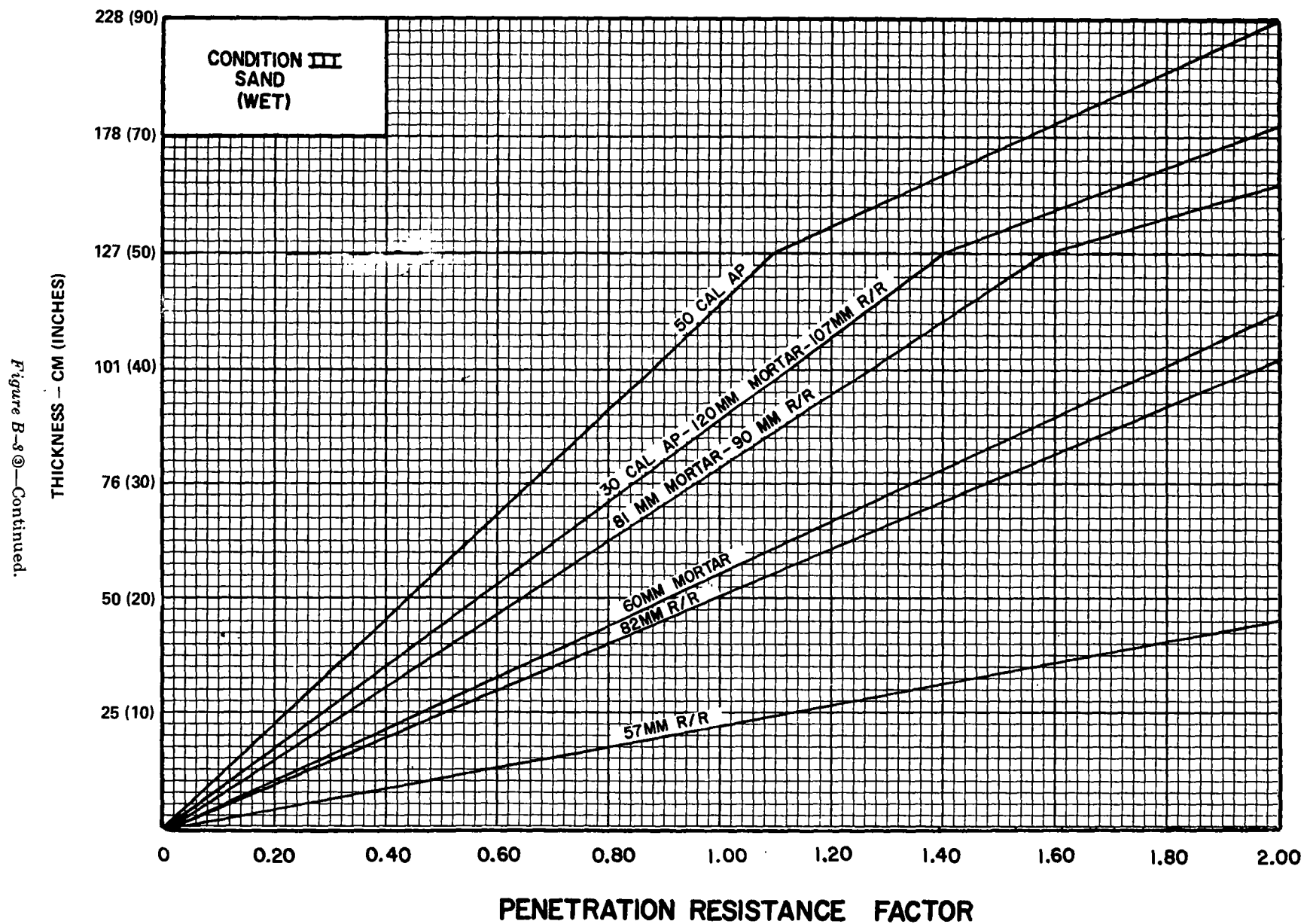


Figure B-3(3)---Continued.

Figure B-3(3). Ballistic graphs -- condition III -- Continued.

Figure B-3④--Continued.

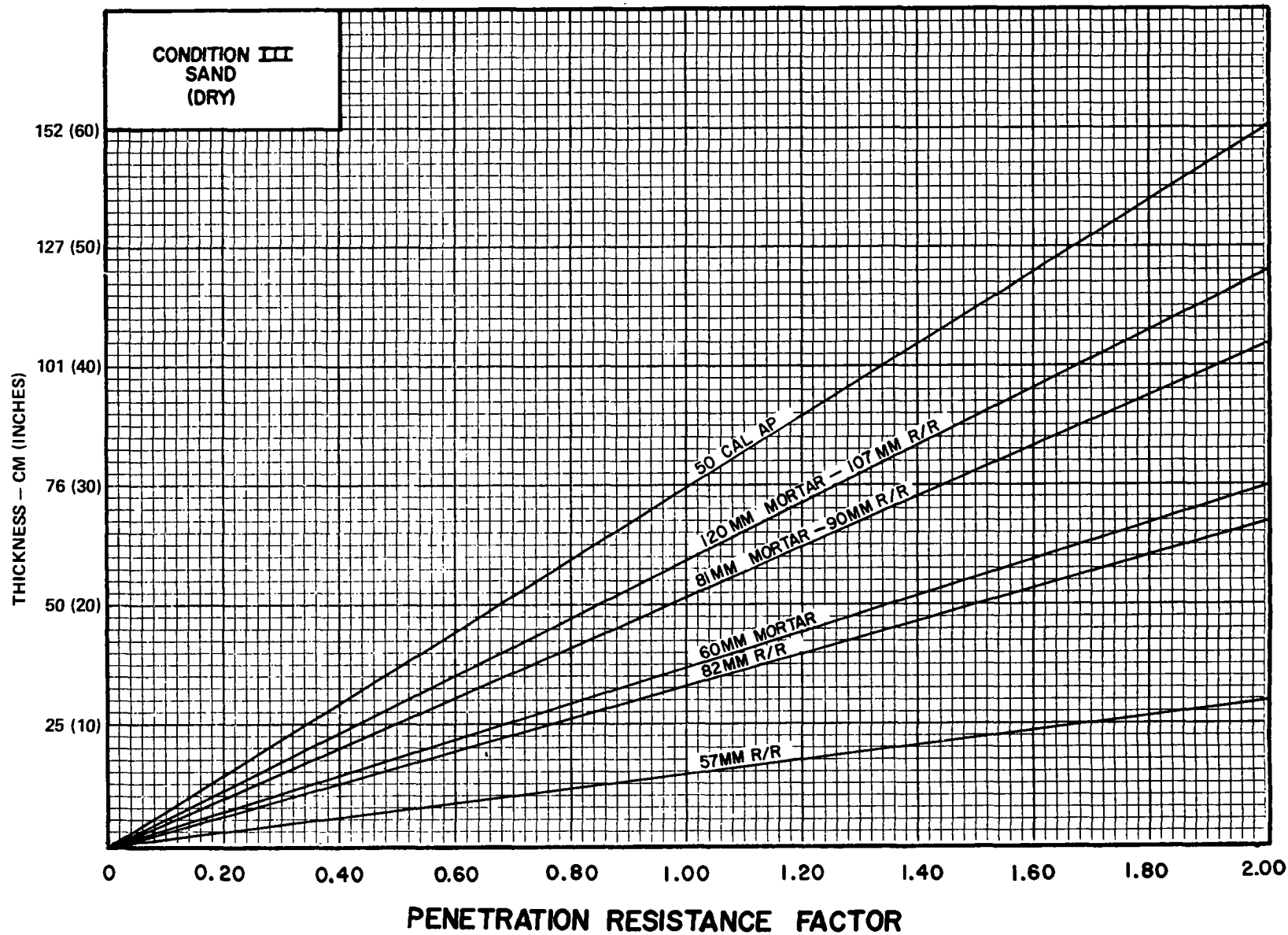


Figure B-3④. Ballistic graphs -- condition III -- Continued.

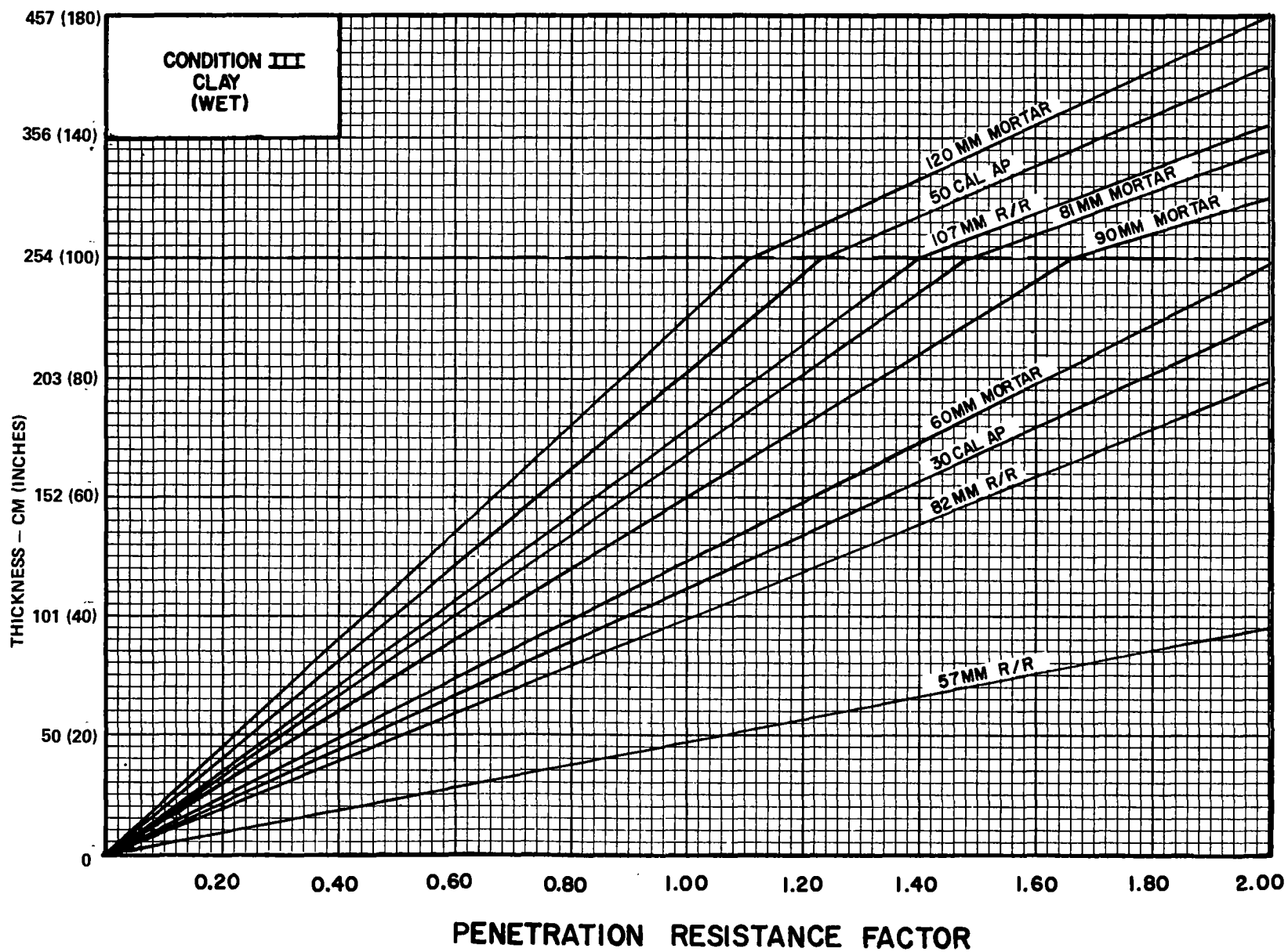


Figure B-3(5)---Continued.

Figure B-3(5). Ballistic graphs -- condition III -- Continued.

Figure B-3⑥--Continued.

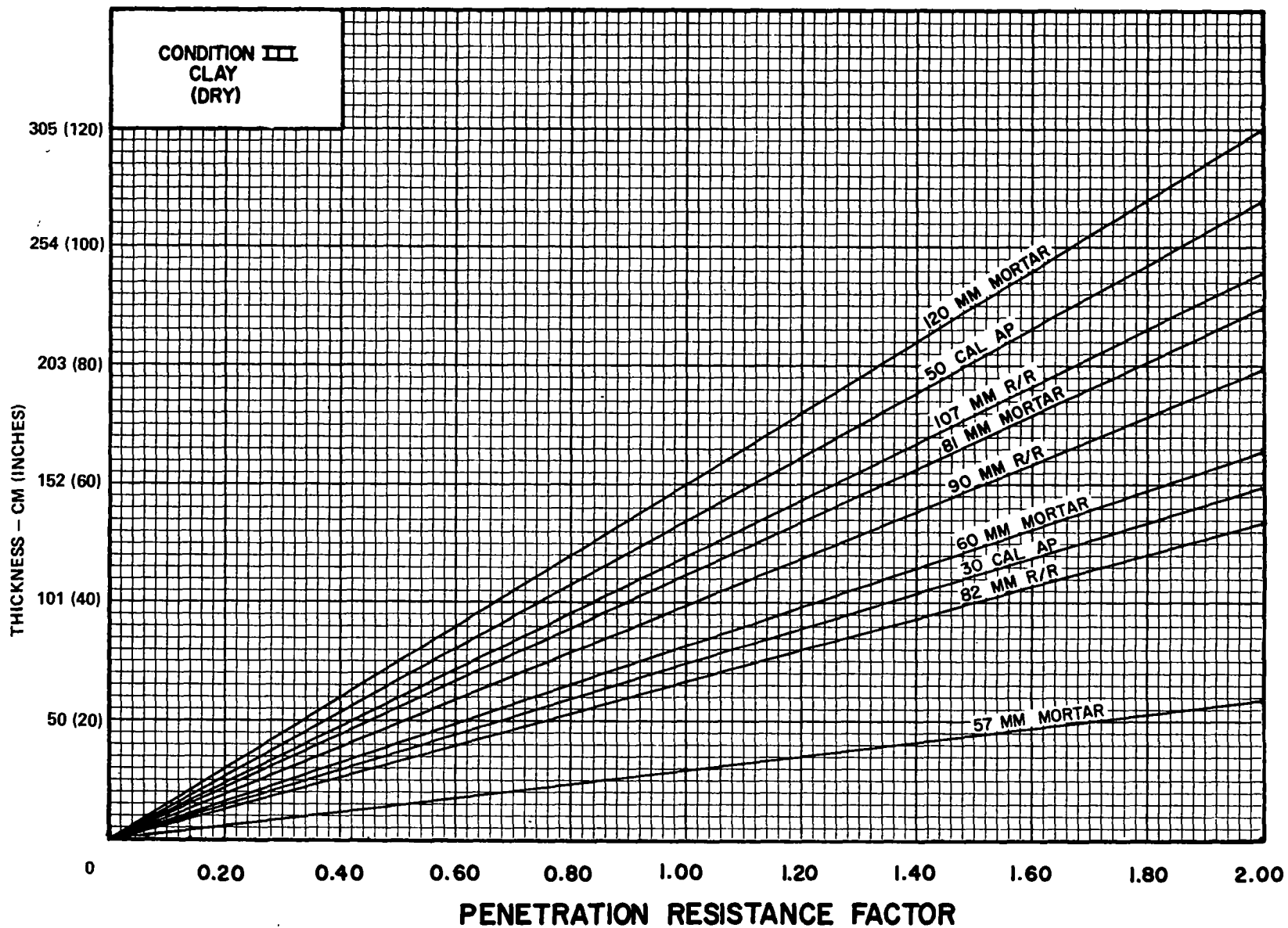


Figure B-3⑥. Ballistic graphs -- condition III -- Continued.

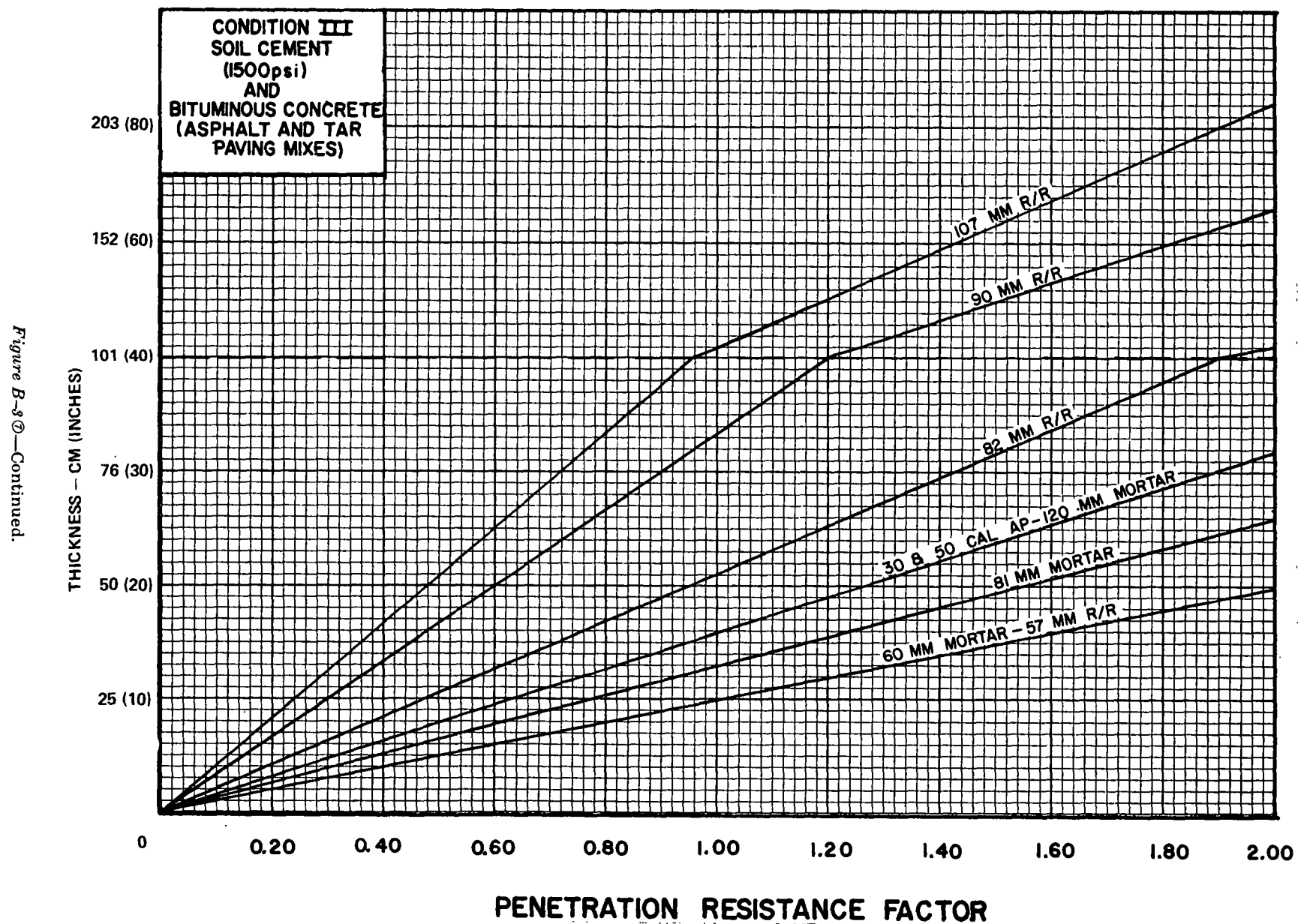


Figure B-3⑦. Ballistic graphs -- condition III -- Continued.

Figure B-3⑧--Continued.

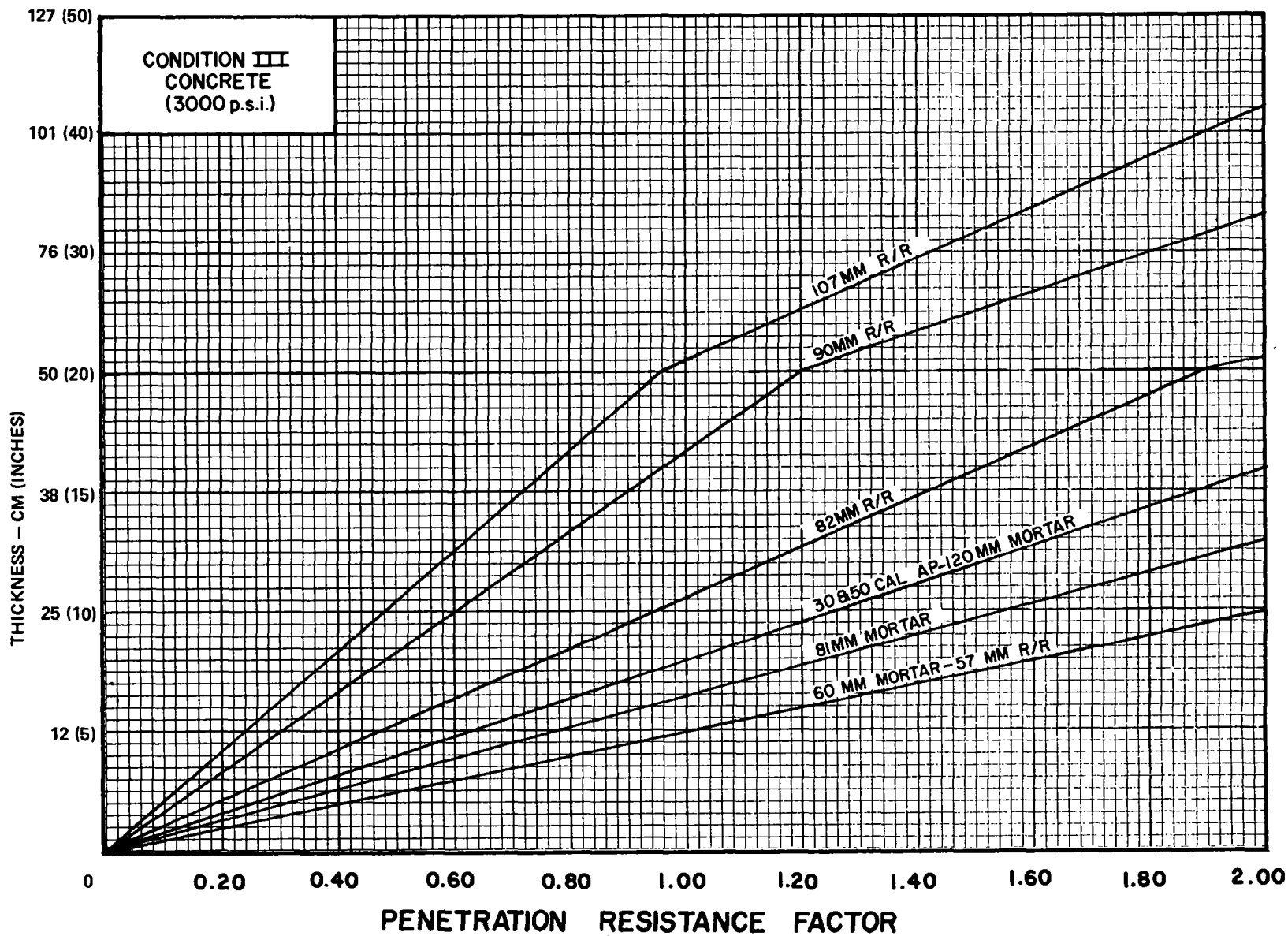


Figure B-3⑧. Ballistic graphs -- condition III -- Continued.

Figure B-3(9)---Continued.

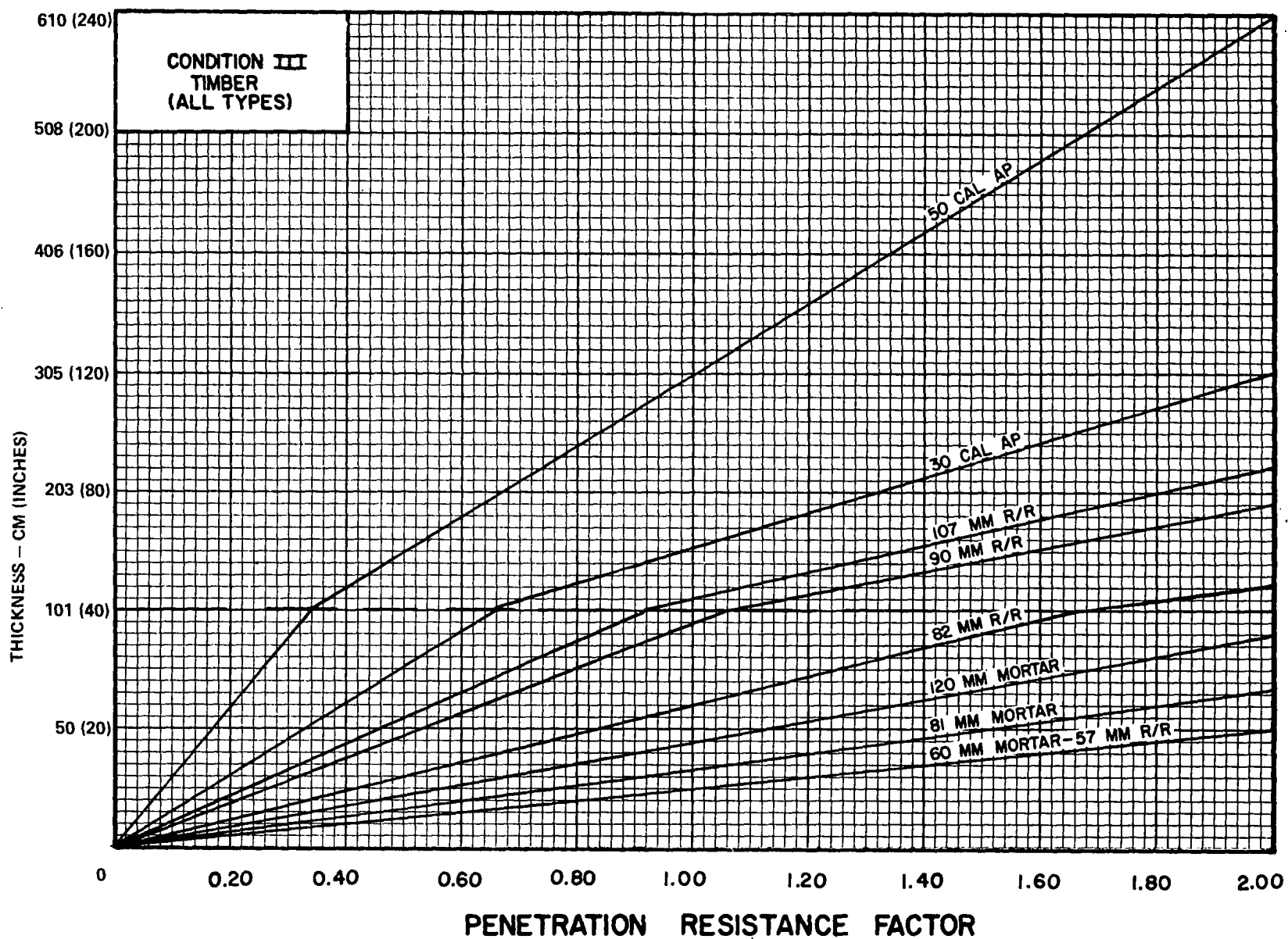


Figure B-3(9). Ballistic graphs -- condition III -- Continued.

Figure B-3@--Continued.

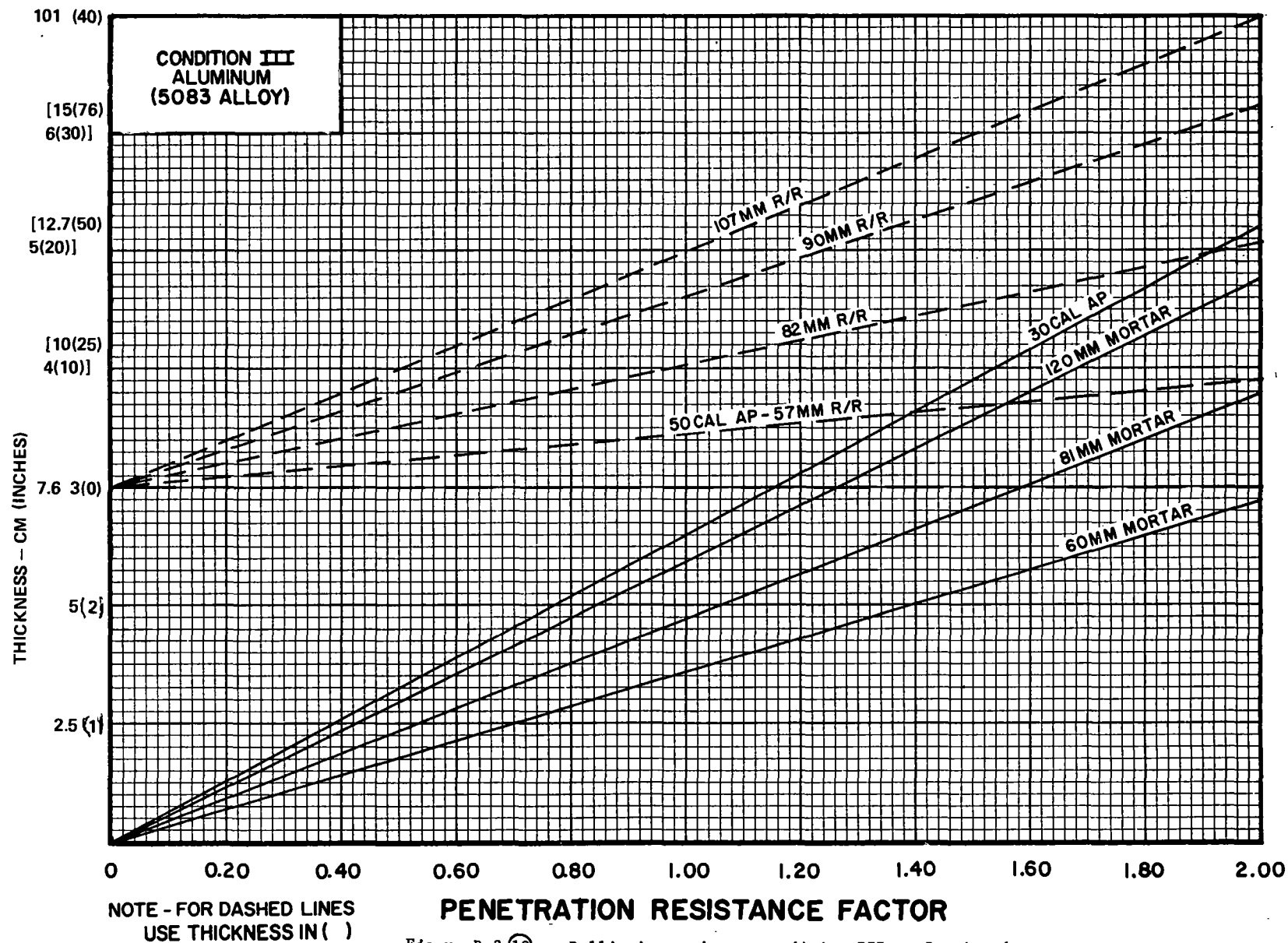


Figure B-3 (10), Ballistic graphs -- condition III -- Continued.

Figure B-3 (11) Continued.

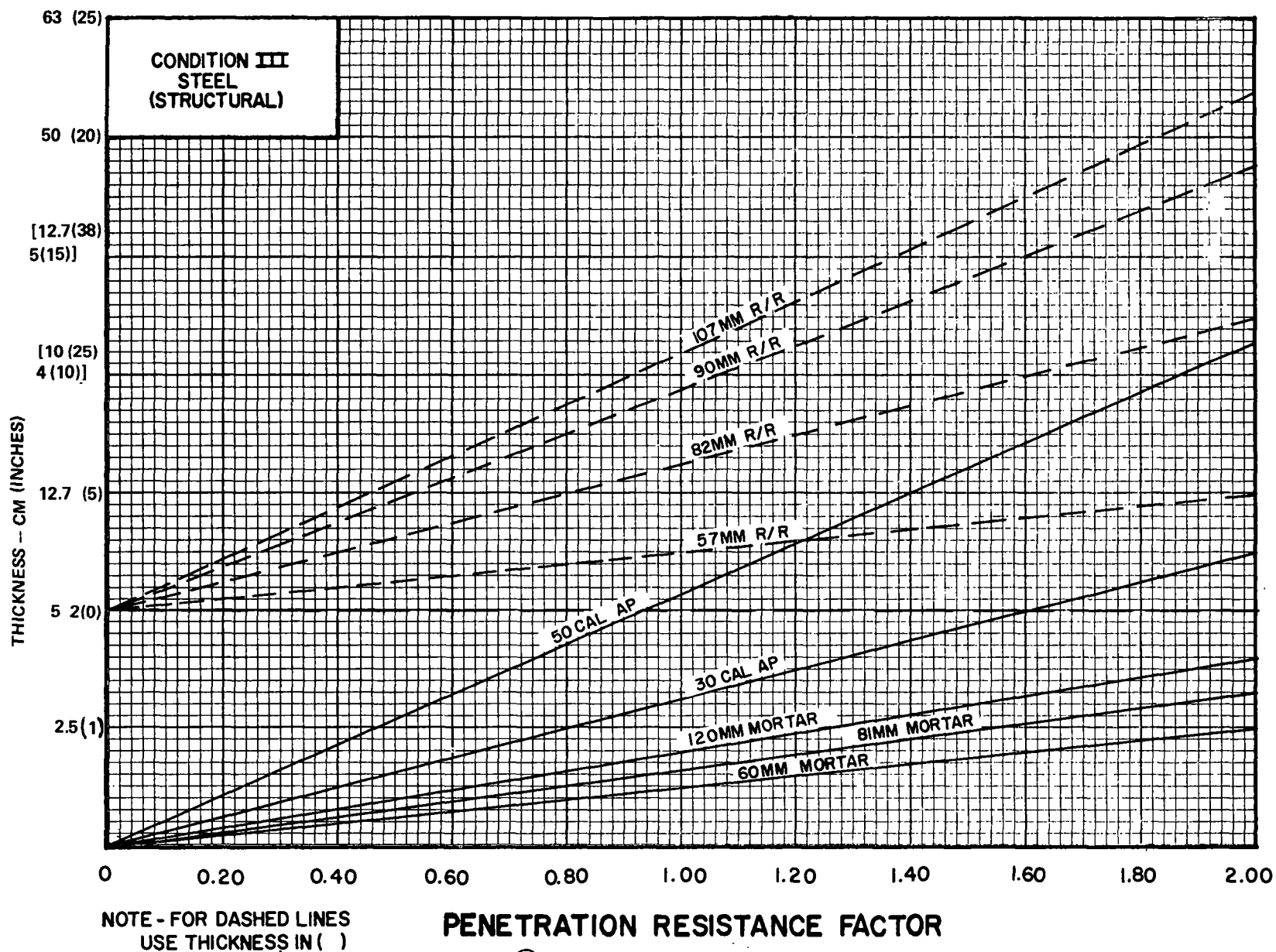


Figure B-3 (11). Ballistic graphs -- condition III -- Continued.

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Table 5-3. Estimating Materials for 3-Meter (10 ft) Sections of Revetments ¹

Material	Unit ⁴	Gravity				Bulkhead					Earth revetment	Free standing wall		Standoff			
		Logs	Dimensioned timber	Landing mat	Steel sheet pile	Logs	Dimensioned timber		Landing mat	Steel sheet pile		Reinforced concrete	Soil cement	Logs	Dimensioned timber	Expanded metal lath	Steel sheet pile
							Field erect	Prefab									
Filler (earth) -----	cu yd -----	$0.4 \left(TH + \frac{H^2}{2} \right)$	$0.4 \left(TH + \frac{H^2}{2} \right)$	$0.4 \left(TH + \frac{H^2}{2} \right)$	$0.4 \left(TH + \frac{H^2}{2} \right)$	0.4TH	0.4TH	0.4TH	0.4TH	0.4TH	0.4(TH+H ²)	NA	NA	NA	NA	NA	NA
Sheathing ² -----	sq ft -----	10(H+1)	10H	10H ⁵	10(H+2)	20H	20H	2H(T+10)	20H ⁵	20(H+2)	NA	NA	NA	10(H+2)	10H	10H	10(H+2)
Waterproofing material -----	sq yd -----	NA	1.1H	NA	NA	NA	2.2H	2.2H(T+10)	NA	NA	NA	NA	NA	NA	NA	NA	NA
Cover material -----	sq yd -----	1.1T+1.7H	1.1T+1.7H	1.1T+1.7H	1.1T+1.7H	1.1(T+2)	1.1(T+2)	1.1(T+2)	1.1(T+2)	1.1(T+2)	NA	NA	NA	NA	NA	NA	NA
Scabbing ³ -----	lin ft -----	100	100	100	100	150	2TH+100	NA	100	100	NA	NA	NA	100	100	50	50
Wire rope cable ⁷ -----	lin ft -----	6H+9T+27	12H+18T+54	6H+9T+18	8H+12T+24	24T+96	18T+72	NA	18T+72	15T+60	NA	NA	NA	9H+12	NA	NA	9H+12
Cable clamps -----	ea -----	60	110	60	75	150	110	NA	110	80	NA	NA	NA	18	NA	NA	18
Nails and spikes -----	lb -----	100	100	20	20	150	150	150	20	20	NA	NA	NA	100	100	20	20
Vertical supports -----	lin ft -----	14(H+3) (2 sizes)	11(H+2)	6(H+2)	NA	12(H+2)	22(H+2)	4H	22(H+2)	NA	NA	NA	NA	NA	3H+6	2H	NA
Wales -----	lin ft -----	NA	NA	NA	3.3H	NA	NA	H(T+10)	NA	3.3H	NA	NA	NA	40	3H	NA	NA
Braces -----	lin ft -----	NA	NA	NA	NA	2.2(H+1)	NA	NA	2.2(H+1)	NA	NA	NA	NA	NA	4.2H	NA	NA
Soil retainer -----	sq yd -----	1.1(H+1)	NA	1.1(H+1)	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Concrete -----	cu yd -----	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	0.4T(H+2)+0.4H	NA	NA	NA	1	NA
Cement -----	cu ft (sack) -----	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	(24 in. footer).	NA	NA	NA	NA	NA
Reinforcing bars -----	lin ft -----	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	TH+0.1H ²	NA	NA	NA	NA
Soil ⁶ -----	cu yd -----	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	11T+27H+11	NA	NA	NA	NA	NA
												NA	0.36(TH+.1H ²)	NA	NA	NA	NA

¹ Material waste factors are not included in estimates. Add 20 percent waste factor for sheathing and 10 percent waste factor for all other materials. Ends (corners) not included; they should be considered in addition to the normal waste factor. All dimensions are in feet.

² For one layer only. Multiply by number of layers if laminated.

³ Scabbing is reusable.

⁴ Key to symbols: H—height in feet
T—thickness in feet

⁵ Increase H to next higher multiple of mat width.

⁶ For soil cement only.

⁷ Estimate based on group of three anchor cables on 10-foot vertical support at intervals specified in drawings.

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